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STATE GEOLOGICAL SURVEY

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

DIVISION OF THE
STATE GEOLOGICAL SURVEY
FRANK W. DeWOLF, Chief

BULLETIN NO. 34

THE ARTESIAN WATERS OF NORTHEASTERN ILLINOIS

By Carl B. Anderson

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FRANK W. DeWOLF, *Chief*

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LETTER OF TRANSMITTAL.

State Geological Survey,
Urbana, June 29, 1919.

Francis W. Shepardson, Chairman, and Members of the Board of Natural Resources and Conservation:

Gentlemen: I submit herewith a report on the Artesian Waters of Northeastern Illinois, and recommend that it be published as Bulletin 34.

It is to be regretted that on account of lack of funds the report could not have been published in 1915 or 1916 soon after completion of the work. However, I feel that the purpose of the book will not be defeated by its late publication and believe that its value will be realized by the industries and cities of northeastern Illinois seeking abundant artesian water supplies.

Very respectfully,

Frank W. DeWolf, *Chief.*

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THE ARTESIAN WATERS OF NORTHEASTERN ILLINOIS

By Carl B. Anderson

PART I

INTRODUCTION

Area Investigated

The region described in this report includes an area of approximately 7,755 square miles in northeastern Illinois. The counties included are Boone, Cook, DeKalb, DuPage, Grundy, Kane, Kankakee, Kendall, Lake, LaSalle, McHenry, Will and Winnebago (see Plate I) with a total population of 2,980,379 in 1910, according to the census of that year. This is 52.8 per cent of that for the entire State, whereas the area is only 13.8 per cent. The city of Chicago, with its two million and more inhabitants is responsible for this unequal ratio between population and area in respect to that of the remainder of the State.

Importance and Purpose of Investigation

The greater amount of water consumed by the inhabitants of this area, excluding Chicago and the towns along the north shore of Lake Michigan, is obtained from underground sources. The industries of Chicago alone pump over 30,000,000 gallons of water per day from deep wells.

A thorough investigation of the underground water resources has therefore been deemed important, special emphasis being laid upon obtaining data in regard to the deep artesian wells since it is from that source that the larger quantities of underground water are procured.

It has been the object of this investigation to ascertain to the greatest practicable extent such information in regard to the underground waters, as quantity, quality, accessibility, distribution, static head, and depths beneath the surface. Chemical analyses have been made of a large number of waters and the results are given. Measurements of the water level were made wherever feasible, or data in regard to the same obtained.

It has been thought that the results of this investigation would be of the greatest practical service if the conditions existing in particular localities were considered individually. The method of treatment has therefore been by counties with detailed discussions regarding the different cities and villages.

Field Work

Essentially all of the field work for this report was done during the summers of 1914 and 1915, although some additional time in November and December of 1913 was spent in Chicago collecting well records and samples of water. The summer of 1914 was devoted almost entirely to work in Chicago and its immediate vicinity during which time the writer was assisted by Mr. H. J. Weiland of the State Water Survey. Data were obtained which made possible the drawing of the contour map of "Potsdam" ground-water level (Plate IV). Likewise a large number of water samples were collected. During the summer of 1915 the remainder of the area was covered.

Importance of Preserving Records

The importance of having exact information regarding underground conditions is becoming more and more evident. To obtain such knowledge and make it available to the public, is the purpose of the Illinois Geological Survey.

drillers' logs

It is usual for the driller to keep and furnish a log of the well to the owner, although in some instances even this is not done. However, the drillers' logs have come to be looked upon with doubt even by the drillers themselves. The personal factor is of much importance, as the logs kept by some experienced drillers are surprisingly accurate. However, in the drilling of a deep well that extends over a considerable period of time, it is very probable that different drillers will have been at work and as the names used by drillers to describe the different kinds of material penetrated is subject to much variation, an inaccurate log will result. As an example, it is not unusual for a crystalline dolomite, which is a limestone with a notable magnesium content, to be called a sandstone; this is particularly true if there are a few sand grains embedded in the dolomitic matrix. The writer has frequently furnished drillers with logs, compiled from a study of drill cuttings, and it has been noted that there has been much more confidence placed in such a record than in one that is just a "driller's log."

drilling samples

There is an increased interest in the collection of drillings among both the enterprising well contractors and the people who are having wells drilled. The writer has usually found that it has been necessary only to call to the well owner's attention the importance of saving drillings in order to have it done. The more progressive well contractors have also been very willing to assist in this matter. There should be a detailed

record of at least one deep well in every city or village as a guide for future drilling and therefore particular care should be taken to have a complete set of samples saved from the first well in a locality. The depths below the surface at which the water stood as the different formations were penetrated together with information regarding any pumping tests should also be carefully recorded. A practice that is becoming more and more common is to have the collection of drillings made a part of the specifications. An accurate log will always be obtained in this manner.

To encourage the saving of samples the State Geological Survey has had special cloth bags prepared for holding samples and these will be sent prepaid to those requesting the same. The Survey will also have the drillings carefully examined by competent geologists, and the detailed logs furnished free of charge. These logs are also kept on file in fireproof cabinets in the Survey offices. There are already thousands of such logs on file, and the information thus obtained is available to the public in all cases in which the owners of the well have not requested that the data be treated as confidential.

DIRECTIONS FOR TAKING SAMPLES

Although the Geological Survey always encloses directions for the collection of samples whenever a set of bags is sent from the office, it will not be amiss to mention here some of the considerations that must be borne in mind. It is not necessary to have a large sample—a few ounces will suffice—but it is advisable to have a sample of the cuttings taken from every "screw," or every five feet of drilling. This is particularly true where the strata are thin and there is a rapid change in the different kinds of rock. The cuttings should not be washed, as in so doing some of the finer material will be lost. The sample should be representative of the material brought up by the bailer. If it is a mixture of coarse and fine material, the sample should be similarly neither entirely fine nor entirely coarse.

The Survey also sends out small handbooks in which drillers may record their logs and any remarks that may pertain to the drilling, as the rate that drilling progresses and the action of the rock upon the bit are all indications of the character of the strata. The water levels and any pumping tests as has been said should be carefully recorded.

EXAMINATION OF SAMPLES

The study of the well drillings should be made by a competent geologist. It is not so easy as it may seem to determine correctly from a small sample of more or less powdered material, the kind of rock that it represents. A description of the material so accurate that it may be possible to visualize the original rock is to be desired.

The reader is referred to a bulletin by Dr. Udden[1] published by this Survey, which gives very complete instructions for the study of well drillings.

Acknowledgments

In order to make a report of this nature at all complete, it is necessary to have the cooperation and assistance of so many people that it is impossible to make individual acknowledgment for all the information obtained. It has, however, been a source of great pleasure to the writer to note the general interest that has been taken in the work and the active assistance rendered wherever possible.

The many drilling firms doing business in this area have freely furnished records and other information at their disposal. Particularly large contributors of such data have been the following: J. P. Miller Artesian Well Company, S. B. Geiger, and the Cater Contracting Company. However, many logs have been obtained from other drillers, and credit is given in the body of the report wherever possible. In many instances these well contractors have taken considerable trouble in having samples of the drillings collected in order that accurate records might be obtained. The city officials in charge of the water departments in the different localities have contributed much data, as have likewise the different firms which are operating deep wells.

The writer particularly wishes to acknowledge the aid rendered in the preparation of this bulletin by his fellow workers of the Illinois State Geological Survey. Mr. F. W. DeWolf, the director, has always been ready with helpful suggestions and criticisms in regard to the general scope of the work. Mr. G. H. Cady has furnished information in regard to the LaSalle area, in which territory he has done much detailed work. Professor T. E. Savage has also rendered aid in the geological interpretation of the well records.

Mr. E. O. Ulrich of the U. S. Geological Survey has kindly given his geological interpretations of some of the detailed well logs. His comments accompany the different logs.

Grateful acknowledgment is due Dr. Bartow of the State Water Survey for assistance in the chemical study of the waters. Almost all the analyses given were made in the laboratories of the State Water Survey.

UNDERGROUND WATERS

Sources

The underground water of any region has with few exceptions the same source as the surface waters; that is, from the rainfall and snow-

[1] Udden, J. A., Some deep borings in Illinois: Ill. State Geol. Survey Bull. 24, 1914.

fall. The water that is thus precipitated upon the earth's surface returns again to the air through evaporation from plant, soil, or water surfaces, is carried off by the streams to the oceans, or sinks into the ground to form the great body of underground water. It is this underground water that supplies the wells of a region and with which we are primarily concerned in this report.

The most of the rocks older than the St. Peter sandstone, encountered in many of the deep wells in northeastern Illinois, do not outcrop at the surface in the State. The proper subdivision and classification of these rocks can not be satisfactorily made from the study of well records or samples of drillings. The field study of these rocks, as well as their underground relations is under investigation in Wisconsin where these strata are exposed at the surface, but final conclusions have not yet been reached. Mr. Ulrich's comments on the logs of a few of the wells that were sent to him are included in this report, but it seems probable that more recent studies in Wisconsin will modify his views. For these reasons it has seemed best to use the old names and divisions for the rocks in this older part of the geologic column in the area under consideration until some agreement has been reached regarding their subdivisions and nomenclature.

Zone of Saturation

DEFINITION

Shallow wells sunk in a flat region of uniform structure and with deposits of essentially the same character have a nearly uniform water level. If the water rises in a number of wells to within a certain distance from the surface, the conclusion is that the rocks are saturated with water to within that distance of the surface. This general level of underground water is called the *ground-water level, ground-water surface,* or *water table;* below it ground-water fills the crevices, joints, and open spaces of the rock to unknown depths. This zone below the ground-water level and to the depths below which it is believed that it is not possible for water to be present is called the zone of saturation.

This underground water is continually being drawn upon; it supplies the permanent streams, escapes through springs, vegetation draws up water from beneath, and both the deep and shallow wells of a region owe their permanence to the underground reservoir.

The water level in wells is known to be higher during the wet seasons than in times of drought; this is because of fluctuations in the ground-water level. During times of heavy precipitation more water sinks into the ground and thus causes a rise in the ground-water level. Whereas in the dry seasons the water level sinks because of excessive drain without replenishment.

FACTORS AFFECTING GROUND-WATER LEVEL

GENERAL STATEMENT

A number of factors affect the depth of the ground-water level beneath the land surface, as well as the amount of available water, and its chemical character. In a nearly flat region with a heavy mantle of coarse material, such as sand and gravel, it is evident that a large amount of the rainfall will sink into the ground; whereas in a region of similar climate but of thin surface deposits, steep slopes, and well established drainage lines, the run-off will be greater, and not so much water will be absorbed by the ground as under the former conditions.

EFFECT OF TOPOGRAPHY

The contour of the ground-water surface is somewhat similar to that of the land surface but not so irregular. Although the ground-water level is higher beneath the hilltops than in the valleys, the maximum differences are not so great as that between the elevations and depressions of the land surface. The water level in the permanent streams is continuous with the underground-water level of the land surface. The movement of the ground water is toward the valleys, and the important source of the permanent streams is the ground water from the uplands.

The water table is not far below the ground surface in valleys, on flood plains, and in the vicinity of large ponds or lakes. It is therefore not an uncommon belief that the wells situated in these lowlands obtain their supply from the nearby large bodies of water. Such is only very rarely the case, as the movement of the ground water is toward points of lower elevation, and therefore the wells in the lowlands draw their water from the same underground reservoir as those on the uplands. However, if wells are located on banks of large streams or lakes and the pumpage is at a greater rate than the inflow from the ground water, there will be a flow toward the well from the body of surface water. Likewise a sudden rise of the water in a stream may cause a temporary underground flow of water away from the stream and into wells.

EFFECT OF SURFACE DEPOSITS

The amount of available ground water depends to a great extent upon the amount and character of the surface deposits. In a sand and gravel deposit there is a notable amount of pore space that may be filled with water. Likewise the flow of water through such material is much more rapid than through that finer in grain. Whenever water is pumped from a well at a greater rate than the rate of inflow of the ground water, there is a depression of the ground-water level. However, because of this more rapid flow in the coarse material, wells tapping such a bed will recover their normal water level in a shorter length of time than those

whose waters come from such deposits as fine-grained clays.

Naturally the most favorable conditions for large yielding surface wells are in flat regions of abundant precipitation and a heavy deposit of coarse material. In certain parts of the area covered by this report, shallow wells of exceptionally large yield can be obtained. The conditions are usually local and are discussed under the different localities.

GROUND WATER IN BED ROCK

Many of the wells in this region draw their water from the bed rock underlying the drift. In those localities where the bed rock is a limestone or a sandstone it is not unusual to obtain wells which yield large amounts. The water from the drift gradually works its way downward to the underlying bed rock. In limestone, the cracks, joints, and other openings are filled by the water; solution of the limestone also takes place, so that in time the openings are much enlarged, and definite water channels are formed. This is particularaly true for that part of this region where the Niagaran limestone is the bed rock.

A sandstone is also favorable for the storage of ground water. This is illustrated in those areas where the St. Peter sandstone underlies the drift. This formation is especially adapted as a reservoir because of the large pore space due to the almost complete absence of cementing material.

It is seen that there is an intimate relation between the drift and bed rock in regard to the water content of the latter. If the conditions of the drift are favorable for the retention of a large amount of the rainfall, then the bed rock will furnish strong wells. In some places more water can be obtained from the bed rock wells than from those which penetrate only the drift. Definite water channels or large crevices may be encountered in which instances the water may not be from the immediate overlying drift, although the source is usually not at a great distance.

Springs

Springs are found along many of the valleys in the glacial drift that covers this region. The water issues usually from some gravel or sand bed outcropping along the sides of a valley. Springs may also occur at the contact of a bed of gravel with an underlying relatively impervious bed, as of clay or shale.

Springs that issue from the bed rock also occur in the outcrop along the larger streams. The water issues from between bedding planes in the rock, crevices, or just above a comparatively impervious layer.

Artesian Waters

DEFINITION

The term "artesian" as used at present refers to water that is contained in a stratum under such pressure that it will rise when tapped by drilling, to a greater height than that of the retaining bed. It is not necessary for a well to flow in order that it can be designated as artesian. In many wells the water may be under sufficient pressure to rise many hundred feet above the water-bearing formation but still lack enough pressure to overflow; whereas another well may tap the same aquifers and flow because it is situated on somewhat lower ground, although the hydrostatic pressure or static head will be essentially the same in both.

The conditions and requisites for artesian waters were outlined many years ago by Professor T. C. Chamberlin[1]. They are as follows:

1. A pervious stratum to permit the entrance and the passage of the water.
2. A water-tight bed below to prevent the escape of the water downward.
3. A like impervious bed above to prevent escape upward, for the water, being under pressure from the fountain-head, would otherwise find relief in that direction.
4. An inclination of these beds, so that the edge at which the waters enter will be higher than the surface of the well.
5. A suitable exposure of the edge of the porous stratum, so that it may take in a sufficient supply of water.
6. An adequate rainfall to furnish this supply.
7. An absence of any escape for the water at a lower level than the surface of the well.

Another list of the essentials for artesian waters was published in 1908 by Myron L. Fuller of the U. S. Geological Survey[2]. His summary is as follows:

1. An adequate source of water supply.
2. A retaining agent offering more resistance to the passage of water than the well or other opening.
3. An adequate source of pressure.

The first requisite is not made specific as regards source, because, as has been pointed out, artesian waters are not derived from a single but from a variety of sources. The second requisite—the retaining agent—may be a stratum, a vein of dike wall, a joint, fault, or other fracture plane, a water layer, or some one of a variety of other agents. * * * * The pressure, although primarily due to variations in level in the different parts of the artesian system, may be transmitted in so many ways and is subject to so many modifying factors that the postulation of a specific cause is impracticable. * * *

It is believed that the three factors stated in the preceding paragraph are all that can be considered as essential to artesian flows, all other postulated

[1] Chamberlin, T. C., Requisite and qualifying conditions of artesian wells: Geol. of Wis. vol. 1, pp. 689-701, 1881. Also Fifth Ann. Rept. U. S. Geol. Survey, pp. 125-173, 1885.

[2] Fuller, Myron L., Summary of the controlling factors of artesian flows: U. S. Geol. Survey Bull. 319, pp. 36-37, 1908.

requisites being in reality modifying or accessory rather than essential factors. These secondary factors may be classified as follows:

Secondary factors of artesian flows

I. Hydrostatic factors (relating to pressure and movement)
   1. Factors mainly affecting pressure.
      a. Barometric pressure.
      b. Temperature.
      c. Density.
      d. Rock pressure.
   2. Factors mainly affecting movement.
      a. Porosity.
      b. Size of pores or openings.
      c. Temperature.

II. Geologic factors (relating to reservoir).
   1. Character of reservoir.
   2. Retaining agents.
   3. Structure of reservoir.
   4. Topographic conditions.
   5. Conditions relating to supply.
      a. Catchment conditions.
      b. Conditions of underground feed.
   6. Conditions of leakage.

DISTRIBUTION OF ARTESIAN WATERS

The above outlined artesian conditions exist in the entire area considered in this report. At depths which vary with the different localities, there are present formations that contain water under great hydrostatic pressure. This pressure is not everywhere sufficient to cause a flowing well, but it is nevertheless ample to cause the water to rise many hundred feet above its containing formation.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING CAPACITY

General Relationships

Beneath an almost unbroken mantle of clay, sand, and gravel, called drift, present over this area, is found the bed rock. The contact between drift and bed rock is clear cut and although the surface of the latter is in its major aspects somewhat more irregular than the former, in general the bed rock surface is much smoother than the drift surface. The consolidated strata can be seen in quarries and also in some railroad cuts where the drift is not too thick. Likewise in a few places the bed rock outcrops, as along Illinois, Rock, and Fox rivers. The bed rock does not have the same character in all localities; for instance, at Chicago and vicinity it is a limestone, whereas along Fox River it is a sandstone, and under the drift in Grundy County, shale.

Surface Deposits

GENERAL DESCRIPTION

The deposit of clay, sand, gravel, and boulders, which covers essentially the entire area treated in this report, was laid down during the glacial epoch. The drift ranges in thickness from a few feet to over 300 feet, and with a probable average over the entire region of 50 to 75 feet. The heterogenous mixture of clay, sand, gravel, and boulders that was deposited directly by the ice is called *till;* the drift that was worked over or sorted by the waters running from the glaciers and then redeposited is called *stratified drift.*

Before glaciation the great mantle of clay, sand, and gravel, which now covers the region, was absent, the streams were cutting away at the bed rock surface that underlies the present drift deposit, and the land surface as a whole was more rugged. As the great ice sheets slowly advanced southward, the original soil and rock debris were ground up and carried along, frozen in and to the base of the glaciers, until as a result of an amelioration of the climate the ice melted, resulting in disappearance of the great ice sheet. All the clay, sand, gravel, and boulders which had been incorporated in, and carried along by, the glacier was then deposited over the land surface to a thickness ranging from a few feet to over 300 feet. Crystalline rocks are found in the drift and as no such rocks outcrop in this region, but only in areas far to the north, this material must have been carried hundreds of miles before deposition. However, the greater proportion of this loose material has been carried only short distances.

The deposition of all this loose material served to efface most of the smaller pre-glacial streams and to alter the courses of many of the larger ones. For example, well drillings revealing the position of buried portions of a pre-glacial valley show that Rock River was forced to leave its channel in a number of places.

The topography of the drift-covered area is of several types, due to the fact that the loose material was not deposited everywhere in the same manner. Each major type will be discussed individually emphasizing its relationship to ground water supplies.

TERMINAL MORAINES

The terminal moraine is that thicker part of the drift which was deposited along the border of the ice sheet while the edge was stationary.

Several of these terminal morainic ridges or belts occur in the region, among which the Valparaiso morainic system is the most noteworthy. It follows the general contour of Lake Michigan, extending southward from the Wisconsin line, through western Lake and eastern McHenry counties, across parts of Cook, Kane, and DuPage counties,

and then southeastward so that it is found in southwestern Cook County and northeastern Will County. The inner border in most places is less than 15 miles from the lake, and the width ranges from 5 or 6 miles to 20 or more miles at the Wisconsin-Illinois line. Minor morainic ridges, such as the branches of the Bloomington morainic system which cross certain of the counties are described under the different counties.

The topography of the terminal morainic areas is as a rule more uneven than that of the surrounding region. Small knobs or knoll-like hills with steep slopes are common; there are numerous depressions between the knolls which may contain lakes. Marshes are also not uncommon.

It is possible to obtain rather abundant supplies of water from most locations in the terminal moraine. Because of the irregularity of the topography, the poor development of the drainage lines and the greater thickness of the drift in the terminal moraine than in surrounding areas, an excessive run-off is prevented and a notably large amount of the rainfall sinks into the ground where it can be drawn upon by the wells. Most of the beds of sand and gravel common in the terminal morainic areas will yield sufficient supplies of water for small villages and for private use.

Along the Valparaiso morainic system, particularly in western Lake County, it is possible to secure unusually abundant supplies from the drift, yet most of the larger wells are continued to the bed rock, for the rock is a limestone so fissured that it is capable of storing extraordinary quantities of the water which seeps down from above. However, the drift is the source of this water, and it is because of the reasons mentioned in the previous paragraph that the underlying limestone contains such abundant supplies.

GROUND MORAINES

The ground moraine is the body of drift lying between the terminal moraines. It covers almost this entire region except in the few places where erosion has removed the drift.

The topography of the ground moraine is less uneven than that of the terminal; the hills are lower and have less slope; the depressions are broader and shallower. It is not uncommon for ground morainic areas to be monotonous plains many miles in extent.

In this region the character of the till is probably the most important factor in determining the ground water possibilities of the ground moraine. Where the greater part of the till is composed of clayey material with only small amounts of sand and gravel, no wells of large yield are possible. However, with slight relief and some sand and gravel beds present, wells of moderate capacities can be obtained. Many wells

dug in the ground moraine, within a few miles of the terminal morainic ridges, yield good supplies. This is true where the rainfall that sinks into the ground on the higher collecting areas encounters a sand bed that extends under the ground moraine.

If the underlying bed rock is a limestone or sandstone, it is best tc continue the wells until these formations are encountered. However, in the regions where the Pennsylvanian rocks, or "Coal Measures", underlie the drift, it is desirable to try to obtain a water supply from the drift because the waters of the "Coal Measures" in many places have a sulphur taste due to the presence of hydrogen sulphide gas.

OUTWASH DEPOSITS

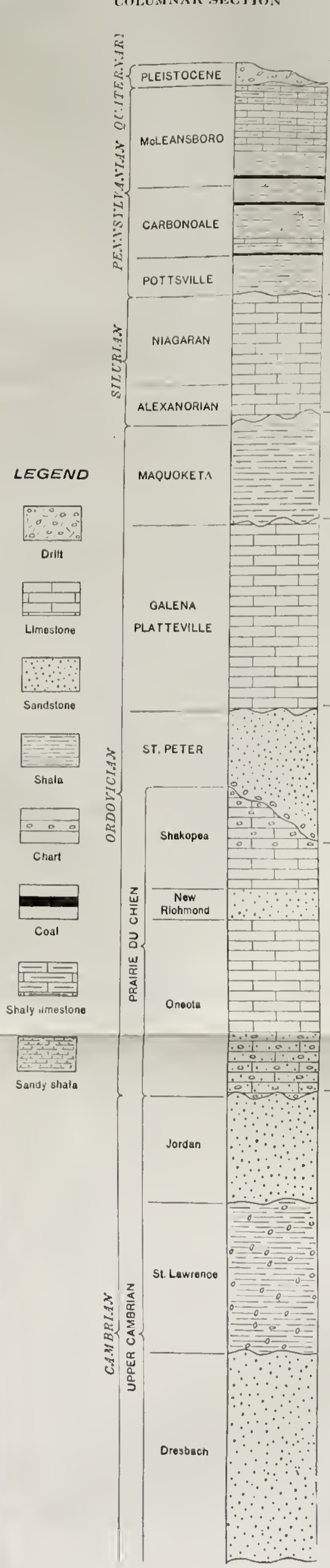
Outwash deposits are made up of drift transported beyond the terminal moraine by water from the melting glacier. These outwash deposits are of the same character as the main body of drift except that they are more or less stratified or sorted by the waters into different beds, each one characterized by a predominance of a certain constituent, as sand, clay, or gravel. The coarser and heavier sediments will be deposited near the terminal moraine, whereas the lighter sands and silt will be carried out much farther. The sediments deposited by the many streams flowing from a glacier may unite, forming a plain-like area spread out in front of the terminal moraine.

The outwash deposits that contain sand or gravel beds of any consequence contain considerable quantities of water, as the porous character of the material enables it to absorb the rainfall. A pervious sand or gravel stratum is commonly included between impervious clay beds; in such a case where this pervious bed either changes to compact material down the slope, or its lower end becomes blocked, artesian conditions may be developed. Thus a number of flowing shallow wells are obtained from the outwash deposits. It is also usual for the pervious deposits of the outwash plain to be connected either directly or indirectly with the terminal moraine, the elevated area and uneven topography of which make it a good collecting reservoir for rainfall; this also tends to produce artesian conditions on the outwash plain which is at a lower elevation.

STREAM OR ALLUVIAL DEPOSITS

The material deposited along stream courses and river bottoms is called *alluvium* or *alluvial deposits.* During times of excessive rainfall the streams become swollen, the swifter flowing waters carrying more detrital material and having greater erosional power than under ordinary conditions. This results in the broadening of the valleys and the formation of flood plains, particularly for the larger rivers. Also in past geologic periods some of the rivers carried much larger quantities of

COLUMNAR SECTION



FORMATIONS				WATER			
Driller's or alternative name	Distribution[1]	Thickness	Description	Yield	Character	Head[3]	Temperature[3]
Glacial drift	Covers bed rock throughout area except for the few small areas where rock outcrops at the surface	*Feet* 0–300±	Clay, sand, gravel, and boulders	Generally sufficient for farm use and locally for small towns	As a rule soft; but locally too hard for boiler purposes	Flowing wells on and adjacent to terminal moraines not unusual. High head common	*Deg. F.* 48°–53°
Coal measures	Chiefly in La Salle and Grundy counties	Maximum 760; generally much less	Dark-gray to black shale predominates, but there is also considerable shaly sandstone and a few thin limestones	Small and confined to certain thin sandstones	High mineral content and sulphurous odor and taste due to presence of hydrogen sulphide gas		
Niagaran	Chiefly in McHenry, Lake, Kane, Du Page, Cook, Will, and Kankakee counties	Maximum 450, in southwestern Chicago	Dolomitic limestone; light gray to bluish gray or light buff, weathering to light buff; contains bits of pyrite and chert and locally considerable bitumen (asphalt)	Variable; 15–20 gallons per minute, average in Chicago; 200 gallons per minute not unusual elsewhere; 400 gallons exceptional	Rather soft and not highly mineralized; but especially in Cook and adjoining counties the hydrogen sulphide content is so high as to make use of water disagreeable. See average analysis on page 90	Flowing wells locally. High head common	50°–55°
Cincinnati	Parts of Boone, De Kalb, Kane, Kendall, Grundy, and counties to the east	Commonly 100-250	Bluish gray compact but soft shale, locally calcareous but never sandy	Not water bearing			
Trenton or Galena-Trenton	Underlies the whole of every county, excepting small areas in La Salle, Grundy, and Kendall counties	300-450	Heavy-bedded, yellowish to cream-colored or yellowish brown dolomitic limestone. In Winnebago county, thin-bedded bluish-gray limestone with a few shaly partings	Moderate supplies, sufficient for private wells and locally small towns. Drilling to underlying St. Peter is recommended	Moderately hard magnesium-calcium carbonate water, locally somewhat sulphurous	Low in Chicago and vicinity. Flowing wells and generally high head in southwestern part of area	
St. Peter	Underlies the whole of every county excepting small areas in La Salle county	Varies greatly and abruptly, but commonly only 100-200. Maximum known, 325	Sandstone composed of rounded to sub-angular, loosely cemented, clear quartz grains, rather uniformly .5 mm. in diameter, with smooth surface and frosted appearance. Base of formation is cherty conglomerate, siliceous oolites, and reddish brown shale	Negligible in Chicago and vicinity where it is less than 20 gallons per minute; adequate supplies for private wells and small towns elsewhere, up to 250 gallons being not uncommon	Variable; in general softer to the north and harder to the south. Locally as in La Salle county, hydrogen sulphide gas gives an unpleasant taste and odor to the water	Flowing wells locally in western and southwestern part of the area. High head common outside of Cook and parts of adjoining counties	
Lower Magnesian	Underlies the whole of every county. New Richmond sandstone known only in La Salle county	Maximum, 700-800, in southwestern part of area; 450 in Chicago; 150-175 at Rockford. Maximum for New Richmond, 188. Basal glauconiferous horizon, 100±	Hard, gray to light buff dolomitic limestone, containing at the top and in certain lower horizons considerable chert, siliceous oolite, and fine sand grains embedded in a dolomitic matrix. Base of the Oneota is sandy dolomite containing glauconite (greensand)	Moderate in general. Good from creviced zones, and from New Richmond where that sandstone is found	Moderately hard from New Richmond. From base, essentially like Potsdam water, but in general somewhat harder and not usable for boiler purposes	Flowing wells from the New Richmond in La Salle county. Data on head elsewhere not available but probably like the Potsdam	
Potsdam	Underlies the whole of every county but is everywhere covered by younger formations	200±	Yellowish white to reddish brown sandstone, quartz grains even-grained, rounded, and large	Best in the area, affording most of the municipal supplies for the area outside of Chicago. Generally capable of more than 200 gallons per minute; a well at Ottawa flowed 400 gallons per minute and an exceptional well in Chicago pumped more than 2,000 gallons per minute for several hours	Highly mineralized and hard, becoming in general more highly mineralized with increasing depth. Sulphates and bicarbonates of calcium and magnesium are especially abundant and, except from certain horizons yielding water with low content of scale-forming salts (see pp. 100, 117, and 141), Potsdam water is generally not suitable for boiler purposes. From the upper part of the Potsdam, the water is pleasant and generally satisfactory for municipal supplies. Wells cannot be drilled too far into the lower divisions however, else water will be encountered which is too salty for drinking purposes	Head low in Chicago and vicinity, where water level is locally 200± feet below the surface; elsewhere high, flowing wells being not uncommon	60°–65°
		300-350	Siliceous dolomitic shales, red and brown chiefly, with thin beds of shaly dolomite and dolomitic sandstones				
		50±	Medium to coarse grained sandstones				

[1] See also Plate III.
[2] See also Table 1.
[3] See also Tables 2, 3, 4, and 5.

Generalized graphic columnar section for Northeastern Illinois, including a summary of data on the artesian waters from the different formations

water than at present; this applies especially to the Illinois and Desplaines rivers. After the recession of the flood stages when the stream occupies only its normal channel, there is left in many places a flood plain. The clay, sand, and gravel that covers this flat land is the material from the drift and bed rock over which the water has flowed.

It is generally recognized that large supplies of water can be obtained from shallow wells on the flood plain and in the valley bottoms. The supposition often is that the source of the water is the streams. On the contrary, the source is the ground water that moves from the uplands toward the lower areas or the valleys supplying the streams with water. In some places flowing wells may be obtained from the alluvial deposits. This signifies alternate pervious and impervious strata with the artesian pressure developed from the higher water table underlying the uplands.

At flood stages the waters from the streams may seep into the wells, because the waters have risen so rapidly that the ground water level has not been able to adjust itself. This condition could not last for long; if the flood stage does not recede in a short time, the ground-water table away from the banks of the stream assumes a higher elevation. However, if the stream waters are polluted, there is danger during such flood periods that the lowland wells may become contaminated.

LACUSTRINE DEPOSITS

In the many small lakes that abound in terminal and ground morainic areas sediments have accumulated until the lakes have become swamps and the swamps themselves have become filled, but such deposits are not of great importance. Even the largest lacustrine deposit of all of them bears no important relation to water supplies, though it constitutes a physiographic feature of noteworthy interest—the plain upon which Chicago is situated.

This flat area was at one time occupied by an extension of a prehistoric Lake Michigan which has been named Lake Chicago and had an outlet down the Desplaines Valley to Mississippi River. Near Summit, southwest of Chicago, the St. Lawrence-Mississippi divide is only about 10 feet above the present lake level.

Bed-Rock Formations

Glacial surface deposits are so variable in distribution and composition that a written description was necessary in order to make even a generalization about them. But the succession of sandstones, limestones, and shales that make up the bed rock underlying the drift is much the same so far as major features are concerned throughout the area, making it possible, therefore, to generalize graphically in a columnar section for northeastern Illinois. (Plate II.) Though thicknesses as shown vary from the truth considerably in certain instances, the section is nevertheless to be taken as representing the average condition. Obvi-

ously the lowest formation is the oldest and those overlying are successively younger, the youngest of all being the glacial surface deposits just described.

Not every formation is represented in all parts of the area, because in some places the younger formations have been removed. For example, near Utica the Pennsylvanian, Niagaran, Maquoketa, Galena-Platteville, and St. Peter rocks have all been eroded completely, uncovering the Prairie du Chien beds, so that only the lower part of the general section, beginning somewhere in the Prairie du Chien group, represents the local Utica section. Again, over all of Winnebago County, Niagaran and Maquoketa rocks have been removed so that Galena-Platteville ("Trenton") rocks immediately underlie the drift and only that part of the section including the Trenton and below is applicable to Winnebago County.

Although originally all these rocks were essentially flat as the sediments from which they were derived were deposited on the sea bottom, they now have somewhat of a slope or *dip* in certain directions, due to movements in the earth's crust subsequent to their deposition. For instance, the limestone commonly known as "Lower Magnesian" outcrops in the vicinity of LaSalle, whereas at Chicago it is a thousand or more feet beneath the surface, though there is no notable difference in the surface elevations at the two localities. The general dip in northeastern Illinois is east and south; thus as one goes west and north from the lake the older rocks will outcrop successively. Surface deposits scores of feet in thickness conceal the bed rock from view in most places, but the accompanying map (Plate III) shows which bed rock lies immediately below the unconsolidated material for every part of the area as closely as it has been determined.

The columnar section is to be applied locally with the aid of such a geological map and all formations above the outcropping one as shown on the map should be omitted from consideration for a given area.

The geologic history which has been interpreted from the character, distribution, altitude, and succession of the various formations has little bearing on the problem of water supplies and is therefore omitted from the report[1].

[1] For those who are interested in the interpretation of the history that has brought about the observed results, other bulletins of the Survey will be oi interest.

Atwood, Wallace W., and Goldthwait, James Walter, Physical geography of the Evanston-Waukegan region: Ill. State Geol. Survey Bull. 7, 1908.

Goldthwait, James Walter, The physical features of the Desplaines valley: Ill. State Geol. Survey Bull. 11, 1909.

Trowbridge, Arthur C., Geology and geography of the Wheaton quadrangle: Ill. State Geol. Survey Bull. 19, 1912.

Cady, G. H., Geology and mineral resources of the Hennepin and LaSalle quadrangles: Ill. State Geol. Survey Bull. 37, 1919.

Geological map of Illinois. Fourth edition. Ill. State Geol. Survey, 1917.

STATIC HEAD

General Statement

The static head (hydrostatic pressure or artesian pressure) of the artesian water in a locality is of great importance, and therefore as much information as possible concerning the static head of the water in different localities was obtained. Detailed information will be found under the discussions of the different localities, but Table I has also been prepared to give a general survey of the artesian-water level in the area. Likewise, a contour map of the artesian water table in the Chicago region has been drawn (Plate IV). This map indicates the level of the water in the artesian wells and does not necessarily represent the static head of the water from a particular formation, because the wells are uncased and therefore the static head is the resultant of all those from the different water-bearing formations penetrated. In reality, however, it is essentially that of the "Potsdam" waters, as this group of sandstones is the important aquifer. In the vicinity of LaSalle the static head represented is in general that of the St. Peter sandstone or New Richmond sandstone, as these are the aquifers that have there been most extensively developed. It will be noted that the water level is lowering, in some localities at a greater rate than in others, so that in time the static head indicated on the map will be too high.

Measurements

METHODS EMPLOYED

It was commonly found that the well owner or person in charge did not know the exact water level. Therefore, wherever possible it was actually measured by the writer or his assistant. The method employed is outlined below, and very satisfactory results were obtained on the wells pumped by the air lift. In most instances it was not possible to determine the water level in wells equipped with deep-well or centrifugal pumps. This is because the pumping machinery covers the entire well opening, so that no weight can be lowered to reach the water level. In a number of such cases the approximate water level was obtained, as it had been measured the last time the pump had been removed from the well for repairs.

The principle used in determining the static head was that of having the water surface in the wells close an electric circuit and measuring the amount of wire extending down from the surface. Two insulated wires twisted together so as to form one, and connected to a small hand-operated magneto at the ground surface, were lowered into the well. The ends of the wire were about 4 or 5 inches apart and properly insulated so that in lowering no contact with the iron pipes would close

Table 1.—*Data regarding the artesian water table in northeastern Illinois*

Locality	Owner of well	Depth of well	Surface elevation	Elevation of artesian water table above sea level: Earliest data: Date	Earliest data: Elevation	Most recent data: Date	Most recent data: Elevation	Recession or lowering of water level: Amount	Length of record	Average recession per year	Principal water-bearing formations[b]	Remarks
		Feet	*Feet*		*Feet*		*Feet*	*Feet*	*Years*	*Feet*		
Boone county— Belvidere..........	City	1950	755	[a] 1891	756	1909	747	9	18	.5	P and SP?	May not be all artesian water; see local description
Cook county— Argo...............	Corn Products Refining Co.	1638	592	[a] 1907	492	1915	405	87	8	10.9	P and SP	
Bellewood..........	Village	1538	635	[a] 1913	560	...	....	....	..	....	P and SP	
Berwyn............	City	1650	605	1909	492	1914	439	53	5	11.	P and SP	
Blue Island	City	1649	641	[a] 1909	469	1914	410	59	5	12.	P and SP	
Chicago— Stock Yards......	Stock Yards Companies	1600 to 2200	592	1889	592	1915	353	239	26	9.2	P and SP	This represents the recession of the water level at the Stock Yards
	Union Stocks & Transfer Co.	2180	592	1909	462	1915	353	109	6	18.1	P and SP	To illustrate the very rapid recession during the past few years
Pitney Court and Archer Ave.....	Peoples' Gas Light and Coke Co.	1800	588	1909	453	1914	375	78	5	15.6	P and SP	
26 St. and Blue Island Ave......	McCormick Reaper Co.	1744	590	[a] 1901	520	1914	371	149	13	11.5	P and SP	
79 St. and Blue Island Ave.....	Grand Crossing Tack Co	1600	586	1911	451	1914	417	34	3	11.3	P and SP	
1225 South Campbell St	Standard Brewery	2200	595	[a] 1892	560	1914	373	187	22	8.5	P and SP	
1734 Fullerton Ave	Deering Harvester Co.	1500	593	[a] 1892	595	1914	459	136	22	6.2	P and SP	When this well was drilled very few others in vicinity
2530 Elston Ave...	Brand Brewing Co.	1600	591	[a] 1899	531	1914	451	80	15	5.3	P and SP	
105th St. and Fort Wayne R. R....	Columbia Malting Co.	1250	587	1900	524	1914	432	92	14	6.6	LM and SP; some P?	See contour map of Chicago and discussion of static head
Chicago Heights...	City	300	656	1894	656	1914	596	60	20	3.	N	Not exactly artesian wells, nevertheless of interest
Clearing...........	Chicago & Western Indiana R. R. Co.	1600	617	[a] 1901	524	1914	405	119	13	9.	P and SP	

Forest Park........	City	1650	625	1901	532	1914	462	70	13	5.	P and SP	See local description; may be some Niagaran limestone water
Forest Park........	City	2012	625	....	....	1915	442	....	..	....	P and SP	See local description; may be some Niagaran water
Harvey............	City	1600	603	1895	593	1915	448	145	20	7.	P and SP	
Harvey............	City (well No. 4)	1600	603	1911	498	1915	448	50	4	12.	P and SP	
La Grange.........	City (well No. 1)	2000	635	1910	588	1914	565	23	4	6.	P and SP; some N?	See local description
Lyons..............	Village	1595	615	[a] 1908	510	1914	478	32	6	5.	P and SP	
Maywood..........	Village	1605	630	1907	550	1913	450	100	6	17.	P and SP	See local description; possibility of error
Melrose............	Village	1620	630	1912	555	1914	550	5	2	2.5	P and SP	
Park Ridge.........	Village	1425	660	1895	650	1914	575	85	19	4.4	P and SP	
Park Ridge.........	Village	1804	660	[a] 1914	575	....	....	....	..	....	P and SP	
Proviso Township.	Chicago & Northwestern Railway Co.	1200	644	[a] 1912	571	....	....	....	..	....	LM and SP	See local description
Proviso Township.	Chicago & Northwestern Railway Co.	1800	644	[a] 1912	606	....	....	....	..	....	P, lower sandstones	See local description
Riverside..........	City	2000	617	1895	597	1914	508	89	19	4.7	P and SP	See local description
Summit............	City	1547	600	[a] 1908	505	1914	443	62	6	10.	P and SP	
Tinley Park........	Village	1060	690	[a] 1915	680	....	....	....	..	....	SP	
DeKalb county—												
DeKalb............	City	890	865	[a] 1895	800	1912	761	39	17	2.3	SP and upper strata	
DeKalb............	City	1306	865	[a] 1912	761	....	....	....	..	....	P and SP	
Genoa..............	City	1500	825	[a] 1900	....	1914	775	....	..	....	P and SP	
Hinckley...........	Village	708	740	[a] 1913	736	....	....	....	..	....	SP	
Sandwich..........	City	600	667	1911	....	1914	650	....	..	....	SP	
Sycamore..........	DeKalb-Sycamore Electric Railway Co.	900	840	1907	793	....	....	....	..	....	SP	
Sycamore..........	DeKalb-Sycamore Electric Railway Co.	1002	810	[a] 1914	793	....	....	....	..	....	SP and LM	
DuPage county—												
Bensenville........	C. M. & St. P. R'y Co.	2201	680	[a] 1913	619	....	....	....	..	....	P	
Downer's Grove...	City	2021	717	1907	....	1913	627	....	..	....	P and SP	
Grundy county—												
Carbon Hill........	Village	1900	565	[a] 1893	590	1915	545	45	22	2.	P and SP; some CM?	Original head not exactly known
Minooka...........	Village	620	620	[a] 1905	....	1915	550	....	..	....	SP	
Minooka...........	Village	2100	614	[a] 1886	660	1915	630	30	29	1.	P and SP	Original head may have been greater
Morris.............	City	765	503	[a] 1894	515	1915	455	60	21	3.	SP	
Kane county—												
Aurora............	City (water works)	2250	630	1899	690	1914	610	80	15	5.3	P and SP	Water level in 1914 may have been lower
Aurora............	City (Talma St. well)	2185	675	[a] 1915	627	....	....	....	..	....	P and SP	
Aurora............	City (River St. well)	2263	622	[a] 1915	624	....	....	....	..	....	P and SP	
Aurora............	Western Wheeled Scraper Co.	1410	688	[a] 1901	658	1914	610	48	13	3.7	P	This should be reliable information
Batavia............	City (old well)	1279	660	1895	680	1914	645	35	19	1.8	P and SP	Original head may have been higher
Batavia............	City (new well)	2000	660	[a] 1915	654	....	....	....	..	....	P and SP	

TABLE 1.—*Data regarding the artesian water table in northeastern Illinois*—Concluded

Locality	Owner of well	Depth of well	Surface elevation	Elevation of artesian water table above sea level. Earliest data: Date	Earliest data: Elevation	Most recent data: Date	Most recent data: Elevation	Recession or lowering of water level: Amount	Length of record	Average recession per year	Principal water-bearing formations[b]	Remarks
		Feet	Feet		Feet		Feet	Feet	Years	Feet		
Kane county—conc'd												
Elgin	City	1350	742	[a] 1903	731	1914	728	3	11	.3	P and SP	There is a possibility water level in 1914 was lower than indicated
Geneva	City	850	675	1911	677	1914	670	7	3	2.3	SP	The water level in 1914 may have been lower than reported
Moose Heart	Fraternal Order of Moose	1840	709	[a] 1914	681	....	....	....	..	....	P and SP	
St. Charles	City	850	748	[a] 1913	698	....	....	....	..	....	SP	
St. Charles	St. Charles School for Boys	1320	788	....	....	1914	695	....	..	....	P and SP	
Kankakee county—												
Kankakee	Kankakee State Hospital	1812	615	....	....	1914	489	....	..	....	P and SP	See local description
Lake county—												
Lake Bluff	Village	1900	680	[a] 1885	725	1914	640	95	29	3.3	P and SP	The early data may not be correct
Lake Forest	Ogden Armour Estate	1623	690	1909	670	1915	649	21	6	3.5	P and SP	
Lake Forest	Ogden Armour Estate	1920	690	[a] 1915	648	....	....	....	..	....	P and SP	
Ravinia Park	Ravinia Park	1096	675	[a] 1903	655	1914	615	40	11	3.6	SP and LM	The data for 1914 may not be correct
Waukegan	C. & N.-W. R'y Co.	2200	600	....	....	1914	620	....	..	....	P and SP	
Zion City	City	1569	648	[a] 1901	683	1914	653	30	11	2.7	P and SP	There is a possibility that the original head was greater than indicated
La Salle county—												
Cedar Point	La Salle County Carbon Coal Co.	1749	653	[a] 1912	563	....	....	....	..	....	GP and SP	
La Salle	Matthiessen & Hegeler Zinc Co.	1619	585	[a] 1913	523	....	....	....	..	....	GP and SP	
Marseilles	City	800	500	....	....	1915	505	....	..	....	SP and NR?	
Marseilles	Private wells	100 to 300	....	....	....	1915	500	20	15	1.3	SP	There has been a gradual recession in the static head, the amount about as indicated
Mendota	City	500	752	1895	705	1915	679	26	20	1.3	SP	
Oglesby	Village	1645	642	[a] 1915	539	....	....	....	..	....	SP	
Ottawa	City	1450	484	[a] 1894	506	1915	485	21	21	1.	P, NR, and SP	

Peru	City	1250	475	1895	560	1915	485	75	20	3.7	GP	Some doubt in regard to the correctness of early data
Peru	Illinois Zinc Co.	1360	463	[a] 1895	570	1914	477	93	20	4.3	GP	Some doubt in regard to the correctness of early data
Peru	Illinois Zinc Co.	1828	463	[a] 1916	493	....	....	....	..	....	NR	The static head of the St. Peter water was 477 feet
Taft	B. F. Berry Coal Co.	1767	680	[a] 1914	540	....	....	....	..	....	GP and SP	
Streator	Various wells	....	....	1895	578	1915	527	51	20	2.5	SP	Early data refers to old city well; recent levels from St. Peter wells at American Glass Co.
Utica	Private wells	475 to 500	175 to 200	[a] 1883	545	1915	520	25.	..	8.	NR	The early data may not be entirely correct
McHenry county–												
Harvard	C. & N.-W. R. R. Co.	900	935	1892	894	1910	875	19	18	1.0	SP	
Woodstock	City	1014	916	....	....	1914	876	....	..	....	SP and LM	
Will county—												
Joliet	City	881	540	....	....	1913	392	....	..	....	SP	See local description
Joliet	City	1550	535	1895	575	1907	527	48	12	4.	P and SP	
Joliet	City	1550	535	[a] 1907	527	1913	477	50	6	8.3	P and SP	Note increase in rate of recession during recent years
Joliet	City (Van Buren St.)	1547	531	....	....	1913	468	....	..	....	P and SP	
Joliet	City (Desplaines St.)	1575	528	....	....	1913	464	....	..	....	P and SP	
Joliet	City (Ruby St.)	1563	544	....	....	[a] 1915	384	....	..	....	P	See local description
Joliet	Citizens' Brewery	1350	542	1905	537	1915	457	80	10	8.	P and SP	
Lockport	City	1922	568	[a] 1895	578	1915	554	24	19	1.2	P and SP	Original head may have been higher
Plainfield	Village	1302	612	[a] 1915	557	1915	557	....	..	....	SP	
Rockdale	Village	662	548	....	....	1915	707	....	..	....	SP	Compare St. Peter wells at Rockford
Winnebago county—												
Rockford	City	1530	712	[a] 1885	745	1915	707	38	30	1.3	P	See local discussion for more detailed account of recession
Rockford	City (No. 7)	1503	735	[a] 1913	....	1915	713	....	..	....	P	
Rockford	City (No. 8)	1500	728	[a] 1915	725	....	....	....	..	....	P	
Rockford	Graham Distillery	....	707	....	....	1914	696	14	27	.5	SP	The rate of recession based upon St. Peter water level in 1887 in city well No. 4
Rockford	City (well No. 4)	710	1300	[a] 1887	710	....	....	....	..	....	....	

[a] Indicates date well was completed.

[b] P—Potsdam group; SP—St. Peter sandstone; LM—"Lower Magnesian" limestone or Prairie du Chien group; N—Niagaran limestone; GP—Galena-Platteville dolomite; NR—New Richmond sandstone; CM—"Coal Measures" or Pennsylvanian system.

the circuit. A small weight consisting of an iron rod about 12 inches in length and .5 of an inch in diameter was fastened at the end of the wire in order to keep it taut. The two ends of the wire were connected to the magneto and the other two ends were weighted and lowered into the well. Current was generated by turning the crank on the magneto as the wire was lowered into the well. As soon as the ends of wire came in contact with the water the circuit was closed and a small bell on the magneto rang. The wire was then marked, pulled up, and measured. After testing a few wells in a locality in this manner the average distance to water was determined, so that in measuring other wells it was not necessary to crank the magneto until after the greater part of the wire had been lowered. The remainder of the wire would be slowly lowered until the ringing of the bell indicated that the water surface had been reached.

Most of these measurements had to be made while the wells were idle, as nearly all the wells were closed at the top, so that it was not possible to lower the wire between the well casing and the water and airpipes. The wire was generally let down the eduction pipe, but in certain cases where the discharge pipes were connected directly with the eduction pipe, this was not possible. In many such cases it was possible to lower the wire down the airpipe by removing a plug or elbow at its top.

This method of measuring by magneto and wire was found to be very satisfactory. A well could be shut down and measured in less than 10 minutes. The chief precaution to be observed was to see that the wire insulations did not become broken and thus cause a short circuit.

Recession

CHICAGO AND VICINITY

It is very probable that the well drilled in Chicago[1] in 1864 was one of the earliest, if not the first, deep well drilled in northeastern Illinois.

This well was drilled to a depth of 711 feet and therefore probably obtained its flow from the Galena-Platteville limestone. The water rose to a height of 80 feet above the surface to an altitude of 692 feet. This well has since been abandoned, but the water level at present in other wells in the vicinity is 150 feet below the surface, or 230 feet lower than at first. Further, the present static head is of water from strata somewhat lower than those penetrated by the well drilled in 1864. It is reasonable to suppose that these waters from the lower zones originally had even a higher head than that recorded in the early drilling.

[1] Schufeldt, Jr., George A., History of the Chicago artesian well, Chicago, 1865. Religio-Philosophical Publishing Association, Chicago, 1897.

The hundreds of deep wells drilled in this area since 1864, have drawn exhaustively upon the underground water resources, causing a recession of the artesian-water table. The amount and rate of lowering has not been the same everywhere. It is in those localities where many wells of large yield have been drilled that the recession is the most marked. This is particularly noted in Chicago and immediate vicinity. The tabulated data indicate the recession and its rate in the different localities and the length of period over which the measurements extend. In general it will be seen that the recession is most rapid where development is greatest, a striking example being Chicago and vicinity.

Detailed notes on recession will be found under the discussions of individual localities.

CHEMICAL CHARACTER OF UNDERGROUND WATERS

General Statement

In the collection of the data for this report the chief attention was centered upon the deep artesian wells of the area. Such wells, 1,000 or more feet in depth, are the great producers of water. Essentially every municipal supply obtained from such wells was examined. Likewise in the different localities samples of water were collected from the wells at the larger factories. Only a few analyses were made of the water from small private wells. In a locality the purpose was always to obtain the knowledge of the ground water that would be of the most importance. Wherever it was possible to secure samples of the water from different depths this was done.

The analyses given in this report, with only a few exceptions, were made in the laboratory of the State Water Survey. The larger number of the analyses—about 115—was made by the rapid method of boiler-water analysis used in this laboratory. The determinations made include residue on evaporation, nitrates, chlorine, alkalinity, iron, sulphates, magnesium, and non-carbonate hardness. The first four determinations are made according to the well-known methods. Iron is determined colorimetrically upon a 100 c. c. portion. Sulphates are determined gravimetrically upon a 250 c. c. portion. Magnesium is determined volumetrically by means of a solution of lime water upon a 100 c. c. portion which has been neutralized with sulphuric acid. Non-carbonate hardness is determined volumetrically in a 200 c. c. portion by means of N-20 soda reagent. Hypothetical combinations of ions have been calculated from these results. This method of analysis is comparatively rapid, but nevertheless indicates the essential characteristics of the water. The few mineral analyses did not differ essentially from those made by the rapid method. The mineral analyses are somewhat more complete and include small amounts of the less important salts.

It would have been possible to include a larger number of analyses by also taking those made by the chemists of the various railroads, water-softening companies, and other industries. However, by having the analyses made by one institution, and by the same methods it was easier to make comparisons between the different waters.

Since the mineral content of the water from any individual well is influenced by a number of factors, a knowledge of the conditions under which the sample was collected is of prime importance. Such data were obtained, as far as possible, by the writer at the time the sample of water was collected.

Factors Affecting the Chemical Character of Well Waters

It would ordinarily be supposed that in a small area artesian wells of the same depth and penetrating the same water-bearing formation should yield similar water. However, such is not always the case. Examples of variations in the chemical character of waters from wells of the same depth will be found under the discussion of Chicago, Kankakee, and other localities. The factors that determine the mineral character of deep well water are depth of well, amount and condition of preservation of well casing, rate of pumping, and age of well.

The depth of the well is a factor in that the water from the same formation in a certain locality, as a city, is essentially of a uniform character, provided that the formation is not subdivided into a number of smaller members containing waters of different characters. It is the addition of water in varying amounts from upper strata that causes the difference in the waters from wells of the same depth. If wells of the same depth also contained the same amount of tight casing, little variation in the chemical character of the water would be noted.

However, the deep wells in this area have generally only enough casing to prevent the caving of any soft formations that were encountered in drilling. The casing as thus used is not for the purpose of excluding water.

The usual method of casing is to place heavy, standard, iron pipe down to bed rock, where a tight joint is made, either by using cement or by driving the pipe, to which an iron shoe is attached firmly into the bed rock. A lighter pipe, or the regulation casing, is used to shut off the Maquoketa shale. Another caving formation, immediately below the St. Peter sandstone, usually requires 50 to 60 feet of casing. Some of the more recently drilled large wells have, besides the surface pipe, another casing extending from the surface to a depth below the Maquoketa shale. A tight joint is here made in the Galena-Platteville limestone. This casing, unless it has deteriorated through age, excludes all surface and Niagaran limestone water.

Wells cased only with the surface pipe obtain water not only from the deep-seated, water-bearing strata, but also from the overlying beds. The water in most wells added from the upper formations, as the Niagaran limestone, Galena-Platteville, and upper part of the Lower Magnesian, is only a small amount. In some places, however, these limestone formations may contain numerous crevices which are natural water channels. In such cases, it may be possible for the final water obtained from the well to have been considerably altered by the addition of this water present in the crevices. Further, two or more water-bearing strata, the static heads of which do not differ greatly, may be penetrated in drilling. The absence of casing in such instances may cause a highly mineralized water from one stratum to greatly affect the better waters from other beds.

In wells completely cased to the water-bearing stratum, the rate of pumping would have no effect, but such wells in this region are few. The rate of pumping may be a factor of great importance in determining the chemical character of the waters from many artesian wells in the area that are not completely cased to the aquifer. As a general rule the static head of the artesian waters is below that of the ground water table, and therefore this water runs into the deep well. In some localities the limestone underlying the drift contains many crevices filled with water which flows into the well from the upper zone and escapes through the deep-seated water-bearing stratum. This same principle is sometimes used by drillers to test the capacity of a well; the rise in the water level in the well when a certain amount is poured into it being equal to the lowering of the level when the same amount is pumped from it. However, such tests are not always conclusive in uncased wells, as crevices may be present that do not contain water but will nevertheless carry away the water that is poured into the well.

To illustrate the effect of the rate of pumping upon the chemical character of the water, consider a 1,600-foot well cased with 75 feet of surface pipe, drawing its water from a 200-foot sandstone encountered at 1,400 feet. The artesian-water level is 150 feet below the surface, and the ground-water table is 40 feet below the ground level. Further, let the bed rock be a creviced limestone that contains a notable amount of water and consider that its mineral content is 400 parts per million. Suppose that the water from the 200-foot, or lower, sandstone has a chemical content of 1,200 parts per million.

Now if water from the creviced limestone runs into the well at a rate of 25 to 50 gallons per minutes, this will be practically the only kind of water pumped from the well, provided that the rate of pumping is not over 25 to 50 gallons per minute. Very little of the water with the

higher mineral content from the lower zone will be obtained from the well. However, as the rate of pumping increases the proportion of the upper zone water will gradually grow less and less. Therefore, when the yield is hundreds of gallons per minute, the water delivered from the well will be essentially that from the lower strata. A well that is pumped for an hour or so and then allowed to remain idle for a corresponding length of time, will deliver water which will have a mineral content varying with the time the sample was collected. For this reason it is possible to have two neighboring wells of the same elevation, same depth, same amount of casing, which yield different kinds of water, because from one a much greater amount of water is pumped than from the other.

The age of the well is a factor in determining the chemical content of the water obtained in that it may have become partly filled and the lower water-bearing formations shut off. Shale formations encountered in drilling may have caved or "bridged" over the hole; in case the shale had originally been cased off, the pipe may have been worn through by the corroding action of the waters, thus permitting the shale to cave. In such cases the water obtained from the well is only from the upper strata. Usually cleaning out the well will give an increased yield, although the character of water obtained may be entirely different from that delivered before cleaning.

Hydrogen Sulphide

GENERAL STATEMENT

Hydrogen sulphide (H_2S) is a gas with an odor similar to rotten eggs. It occurs dissolved in some ground waters, which are usually spoken of as sulphurous. It is corrosive when present in amounts sufficient to be noted by taste or odor. Its presence is objectionable in the waters used in such industries as laundries, dye works, and bakeries.

Through hydrogen sulphide is encountered in considerable quantity in but two water-bearing strata of this region, yet it has seemed worth while to discuss it at this point, because its presence in abundance produces such noticeable effects on the nature and usefulness of the water, and because many large and important wells, particularly in the Chicago area, yield water with a very high content of the gas.

METHODS OF ANALYSIS

Assays of the waters of representative wells in Chicago and vicinity were made in the field by H. J. Weiland of the State Water Survey, who assisted the writer during the summer of 1914.

The standard method of analysis was used except for slight modifications for convenience in the field[1] The water to be tested was poured into a liter bottle graduated at intervals of 10 c. c., until the 500 c. c.

[1] American Public Health Association, 1912, p. 69.

mark was reached. Then 10 c. c. of one hundredth normal iodine and 1 gram of potassium iodide were added. After sufficient time had elapsed (2 or 3 minutes) to permit the reaction to reach equilibrium, the excess iodine was determined by titration with one hundredth normal sodium thiosulphate until a straw color was obtained. One cubic centimeter starch solution was then added and the titration continued until the blue color disappeared. The hydrogen sulphide in parts per million is calculated by multiplying the difference in the number of cubic centimeters of iodine and sodium thiosulphate used, by the factor 0.34.

OCCURRENCE

NIAGARAN WATERS

The wells in Chicago, a few hundred feet in depth and which penetrate the Niagaran formation, yield a water of low mineral content and variable amounts of hydrogen sulphide. The determinations are given in the mineral analyses in the appendix. The average amount in the 34 assays made was 1.31 parts per million; the range was from .39 to 5.87 parts per million. The average content is sufficient to give the water a somewhat sulphurous taste and a slight odor. The source of the hydrogen sulphide in the Niagaran limestone waters has not been determined. Occasionally small bits of iron pyrites are found in the drillings from this formation. It may be that some of the hydrogen sulphide is formed through solution and hydrolosis of the pyrite. The Niagaran limestone in places as at Stony Island shows blotches of a bituminous substance. In view of the prevalence of hydrogen sulphide in petroleum-bearing rocks, this may be the explanation for its occurrence in the Niagaran limestone. It may be mentioned in this connection, that a little gas and some petroliferous substance were encountered in the Niagaran limestone in drilling a well on the estate of Ogden Armour in Lake County.

DEEP WELL WATERS

Early in the investigations it was noted that the waters from some of the deep wells were sulphurous. These waters had all the characteristics of Niagaran limestone water, such as similar mineral analyses, low temperatures, and noticeable amounts of hydrogen sulphide.

The explanation of the similarity of the deep-well waters to those from the Niagaran limestone is to be found in leakage into uncased wells from this formation. These wells are cased only to the bed rock, or Niagaran limestone. Therefore if a well is of small bore and the pump is not operated at a much greater rate than the water from the Niagaran limestone flows into the well, the final yield will resemble that from this upper formation to a greater extent than that from the lower strata.

The amount of water obtainable from the Niagaran limestone does not exceed 20 to 40 gallons per minute. If a 1,600-foot well is not operat-

ing at a greater rate than 50 to 75 gallons per minute, the greater amount of the water obtained is from the Niagaran. As the rate of pumpage increases, more and more water is drawn from the lower strata and the per cent of dilution from the upper waters becomes less. If the well is delivering 200 or more gallons per minute, the amount obtained from the Niagaran limestone becomes negligible.

It was noted that the hydrogen sulphide content in waters from wells pumped by air was less than that from those pumped by deep-well pumps. This is because the air oxidizes the hydrogen sulphide according to the following reaction:

$$2H_2S+O_2=2H_2O+2S.$$

In one well at River Forest small particles of sulphur were found in the water of the discharge tank.

In Chicago and its immediate vicinity the waters from the deep wells that deliver 200 and more gallons per minute do not commonly contain over .3 parts per million and in many instances less. However, this does not apply universally to the deep wells of the area, for the St. Peter water in many places is sulphurous.

TEMPERATURES OF UNDERGROUND WATERS

General Statement

It is commonly known that the waters from the shallow wells are cooler than those which come from the deep, artesian strata. This indicates that there is an increase in the temperature of the rocks themselves as the greater depths are penetrated. This is shown further by the temperature determinations that have been made in mines and deep borings, some of which extend to depths of over a mile. The rate of increase in temperature as the earth's crust is penetrated is called the *geothermal gradient.*

The geothermal gradient for that part of the earth's crust as deep as it is known is generally assumed to be on the average 1 degree Centigrade for 30 meters or 1 degree Fahrenheit for 55 feet. In connection with the present study of the underground waters of northeastern Illinois it was decided to determine the temperatures of the well waters wherever practicable, and then to compare the geothermal gradient obtained from these results with those existing in other regions.

Methods of Obtaining Temperature

The temperatures were taken with an accurate chemical thermometer graduated in degrees, and the tenths of a degree were estimated. The thermometer was held in the water as it issued from the mouth of the well and the reading obtained without removing the instrument. It

must be considered whether this temperature represents that of the water-bearing formation. These artesian wells usually obtain the water from one main stratum, although in the deeper wells there may be two or more productive formations. The waters of the shallow depths are much cooler than those from the lower horizons. Therefore in obtaining the temperature of a deep-well water it must be decided whether the lower, warmer waters have been diluted by the cooler ones from the upper horizons.

The wells in practically the entire area have only about 75 feet of surface pipe and 200 feet of casing for the Maquoketa shale. In case any other caving formations are encountered they are also cased off. The casing as thus used excludes very little water. Although these uncased limestones generally contain only a small amount of water, in exceptional cases they afford abundant supplies. An example of a large amount of cool, upper-zone waters entering a well is at Kankakee; the conditions which exist at this locality are explained later.

It is generally possible to determine whether the deep-well waters have been diluted to any considerable extent by surface waters, because of differences in chemical character and temperatures. The method of pumping is also likely to alter the temperature one way or another.

Chicago Well Waters

The temperatures of the well waters in Chicago are believed to represent essentially those of the water-bearing formations, because of certain conditions, given below, that exist in this locality. In this city a large number of wells exceed 1,500 feet in depth, so that many temperature tests could be made. The temperatures given are of wells pumped at a high rate, at least 200 gallons per minute and ranging up to 1,500 gallons. Therefore, although the wells have only enough casing for the surface material and any other caving formations that may be encountered, the small amount of surface water that may get into the well has practically no effect in cooling the lower waters. Further proof that this deep well water is from the lower strata is that the chemical analysis is much different from that of the shallow well water. The quantity of water that can be obtained from the shallow wells in Chicago is small. The average Niagaran limestone well does not yield over 20 gallons per minute, and in many cases the yield is much less.

Most of these deep wells are pumped by means of an air-lift system and the water is thus discharged without passing through a pump. There is very little likelihood that the water is heated by the compressed air when the high rates of pumping are taken into consideration. If this were the case it would tend to increase the gradient which is nevertheless far below the normal.

In determining the geothermal gradient it is necessary to know the temperature of the invariable horizon. This horizon is usually regarded as being at about 50 feet below the surface, although in places it may be much deeper. The temperature at this depth is just below the influences of those at the surface. The temperature of this horizon is generally taken as the average for the locality as determined for a period of many years. It is possible, if not probable, that the temperature of the invariable stratum is higher than the mean annual temperature of a locality. This has been recognized by A. C. Lane[1] and others. The chief reason given to explain the difference is that the snow covering in winter prevents the ground from becoming as cold as the surface air. This modification would therefore be especially applicable in the temperate zone and in the higher latitudes. It is worthy of note that in no case was the temperature of the water from a shallow well in Chicago within 3° F. of the mean annual temperature.

DEEP WELLS

DEPTH OF INVARIABLE STRATUM AND TEMPERATURE

The annual temperature at Chicago as determined over a period of 31 years is 48° F. This figure is used as the temperature of the invariable stratum, which is regarded as lying at a depth of 50 feet. In the table of temperatures of deep well waters of Chicago the calculations have been made on a basis of 50° F. as the invariable temperature as well as on a basis of 48° F. As the drilling has usually passed through the water-bearing formation, the temperature of the water obtained can not be said to be the same as that at the bottom of the well. The water-bearing formation in Chicago of the 1,650-foot type of wells is usually about 200 feet in thickness. Therefore in the geothermal calculations the maximum depth is taken as about 100 feet less than the depth of the well. In the deeper wells a similar reduction is used.

GEOTHERMAL GRADIENTS

The table of the Chicago wells (Table 2) includes only the most reliable readings that have been taken. The average temperature of wells of the 1,650-foot class is 59.4° F. This would give a geothermal gradient of 132 feet per 1° F. if the temperature of the invariable stratum is taken to be 48° F. and its depth 50 feet. A depth of 1,550 feet is taken to represent the horizon yielding the greatest amount of water. If the calculations are made in an assumption that the invariable temperature is 50° F. the geothermal gradient would be 160 feet per 1° F.

In the wells over 2,000 feet in depth the temperature of the water is about 63.4° F. and the gradient is about 128 feet per 1° F. The

[1] Lane, A. C., Michigan Geol. & Biol. Survey, Vol. 2, p. 759, 1911.

TABLE 2.—*Temperatures of the waters from representative deep wells in Chicago*

Owner.	Depth	Pumpage	Temperature of water	Geothermal gradient in ft. per 1° F.	
				Considering temp. of invariable stratum as 48° F.	Considering temp. of invariable stratum as 50° F.
	Feet				
Armour Packing Co.	1600	1000+	59.1	131	159
Chicago Packing Co.	1615	400	59.3	130	157
Crystal Ice Co.	1614	200	59.7	126	151
Garden City Brewery	1410	[a]200	59.2	121	148
Illinois Vinegar Works	1689	350	59.2	137	167
Monarch Brewery	1575	300	59.3	126	153
Darling Packing Co.	1683	300	59.6	132	160
Morris Packing Co.	1622	300	59.0	134	163
Sulzberger, Sons & Co.	1690	590	59.5	134	163
Swift & Co., No. 5 house well	1643	250	59.7	128	153
Western Packing Co.	1650	[a]225	59.8	127	153
Illinois Vinegar Works	1942	200	62.0	121	150
Swift & Co. Hog House	2008	250	62.5	128	148
Swift & Co. Bone House	1979	300	62.3	128	149
Swift & Co., No. 3 well	2000	300	63.7	118	135
Union Stock Yards (West well)	2180±	150	64.5	123	140
Union Stock Yards (East well)	2180±	150	65.4	117	132

[a] Indicates deep-well pump; all others equipped with air lift.

second water-bearing stratum is struck in Chicago at about 1,900 feet, and the water obtained is a few degrees warmer than that from the zone between 1,400 and 1,600 feet.

SHALLOW WELLS

A number of temperatures of shallow well waters were obtained, but they are not considered important as indicative of rock temperatures (Table 3). There are a number of reasons why the shallow well data are not comparable with those of the deeper wells. These wells vary in depth from less than 200 to more than 500 feet, and the water is in crevices of the limestone. It is possible that in a well 400 feet deep the greater amount of water is obtained from crevices less than 100 feet below the surface. Therefore, the water temperatures of wells 200 and 400 feet in depth might be the same. It is likewise not possible to obtain the temperatures until the water has passed through the pumps, which very probably affect the results. The amounts pumped are usually less than 20 gallons per minute. This makes it possible for changes to occur between the original temperature of the water in the well and that obtained at the surface.

The results primarily indicate the average temperature of the shallow well waters in Chicago as delivered from the pumps. It is not advisable to construct geothermal gradients from these data.

TABLE 3.—*Temperatures of waters from shallow wells in Chicago*

Owner	Depth	Pumpage	Temperature
	Feet	*Gal. per min.*	*Degrees F.*
Bissel Laundry	?	25	52.6
Bunge Vinegar Works	312	10	50.8
Drexel Arms Hotel	185	8	54.1
Lehigh Valley Coal Co.	365	15	54.0
Miller and Hart	300	12	53.2
J. Mohr & Sons	350	35	55.8
Murray & Nichel	286	30	55.0
Norris Elevator Co.	348	30	55.9
Rialto Elevator Co.	401	15	53.1
J. Rosenbaum Grain Co.	502	6	54.5
Star & Crescent Milling Co.	340	15	52.9
Willard Sons, Bell & Co.	187	7	55.6
Wisconsin Steel Co.	405	20	54.5
Winamac Apartment	400	20	53.8
Average	337	18	53.9

TABLE 4.—*Temperatures of waters from deep wells in northeastern Illinois, not including Chicago.*

Locality	Owner	Depth	Pumpage or flow	Temperature of water	Geothermal gradient In feet per 1° F. Considering temp. of invariable stratum as 48° F.	Considering temp. of invariable stratum as 50° F.	Remarks
		Feet	*Gal. per min.*	*Degrees F.*			
Boone County—							
Belvidere......	City	1803	200	52.6	....	....	Very probably considerable water is obtained from zones a few hundred feet from surface
Cook County—							
Blue Island...	City	1649	[a]300	59.0	136	163	
Maywood......	City	1605	[a]700	57.7	150	188	
River Forest..	City	1000	[a]150	52.0	....	....	Probably dilution by Niagaran limestone water
Summit.......	Village	1547	225	58.0	140	174	
De Kalb County—							
Sycamore......	City	902	150	51.5	....	....	Very cool for this depth, either affected by pump or dilution by water from upper zones
Du Page County—							
West Chicago..	City	775	100	50.2	....	....	Probably Niagaran limestone water for the most part
Grundy County—							
Minooka.......	Village	2280±	[b]50	66.5	115	129	Some doubt regarding depth
Kane County—							
Batavia.......	City	2001	1140	59.2	165	201	
Aurora........	City	2263	[b]150	63.5	136	157	
Aurora........	Aurora Bleachery	1280	[a]200	57.2	123	156	
Kankakee County							
Kankakee.....	Asylum	1812	[a]250	61.5	123	145	
Kankakee.....	Asylum	1847	[a]250	56.2	....	....	Diluted by waters from Niagaran limestone; see local description
Lake County—							Some doubt regarding depth
Lake Bluff....	Village	1900±	75	63.7	111	128	
Ravinia Park..	Park	1096	75	55.6	124	169	
Zion City......	City	1568	[b]200	61.2	107	126	
LaSalle County—							
Marseilles.....	City	800	[b]100	54.0	133	200	Some doubt regarding depth
Ottawa........	City (No. 2)	1200	[a]175	57.5	111	140	After flowing through about 250 feet of pipe
Ottawa........	J. P. Catlin	1840	[b]3	61.0	130	153	After flowing through about 50 feet of pipe
Streator.......	American Bottling Co.	[c]700±	[a]95	59.5	57	68	Surface rocks are "Coal Measures." Some doubt regarding depth
Streator.......	Western Glass Co.	[c]587	60	59.7	46	55	Surface rocks are "Coal Measures"

[a] Pumped by air-lift, all others with some form of deep-well pump.
[b] Flowing well.
[c] No other deductions made from depth of well, except 50 feet for invariablestratum.

Well Waters Outside Chicago

DEEP WELLS

Temperatures of well waters have also been obtained in localities in this area outside of Chicago (Table 4). These, as a whole, have not been so satisfactory as those determined in Chicago. In many instances it was not possible to take the temperature immediately after the water issued from the well, but only after it had flowed through varying amounts of pipe. Likewise, in most cases the water first passed through pumps, an operation that affects the temperature. The amounts pumped were usually less than those in Chicago, and thus a greater amount of the cool upper-zone waters was permitted to become mixed with that from lower depths. The temperatures given are those considered the most reliable.

The effects of the surface ground water entering the well are shown in a few cases where the water from a deep well is similar in temperature to that from one only a few hundred feet in depth. The well at Belvidere has a depth of 1,803 feet, and the water should have a temperature of at least 59° F., whereas it is only 52.6° F. It is very probable that a large amount of the water is from horizons only a few hundred feet below the surface. Another anomaly is seen at Kankakee, in the case of two wells only 275 feet apart. The wells are 1,812 and 1,847 feet in depth, and the pumpage is approximately 250 gallons per minute from each. The temperature of the water from the 1,812-foot well is 61.5° F. and that from the 1,847-foot well is 56.2° F. There is also a marked difference in the chemical character of the waters. The water with the higher temperature contains a much greater amount of dissolved mineral matter than the one with the lower temperature. The wells are approximately the same depths, but the anomaly is made more striking by the fact that the cooler water is furnished by the well of slightly greater depth.

The difference in temperatures is due to the entrance of cool, underground surface water into one well at a greater rate than the quantity pumped. This water is prevented from entering the other, the 1,812-foot well, by means of the surface casing. This surface pipe is 75 feet in length in the 1,847-foot or cool-water well, and 100 feet in the other one. The locations are only a few hundred feet from the Kankakee River and the curb elevations are not over 12 feet above the water level in the river. It may also be mentioned that there is a great difference in the static head of the waters in the two wells. The level in the 1,847-foot or cool-water well is only 51 feet below the surface, whereas in the other one the level is 126 feet. The latter figure is the true static head of the artesian water from the deep-lying formations; the other level is only that of the shallow, underground water table.

TABLE 5.—*Temperatures of waters from shallow depths in northeastern Illinois, not including Chicago*

Locality	Owner	Depth	Pumpage or flow	Temperature	Character of strata and remarks
		Feet	*Gal. per min.*	*Degrees F.*	
Cook County—					
Barrington.....	Village	315	400	52.0	Drift 200± feet; Niagaran limestone
Desplaines.....	City	125	[a]50	51.3	Drift
DuPage County—					
Downers Grove.	City	250	75	50.2	Drift 85; Niagaran limestone
Hinsdale.......	City	275	400+	52.5	Drift and Niagaran limestone
Naperville......	Mr. Goodwin	Spring	[b]10	51.5	Drift
West Chicago...	City	775	100	50.2	Water is probably all from drift and upper part of the Niagaran
Wheaton.........	City	175	200	52.0	Drift 110 feet; Niagaran limestone
Kane County—					
Aurora.........	Aurora Brewery	Spring	[b]5	54.0	Temp. of water in pool; probably high
Elgin..........	Elgin Watch Co.	500±	50	54.7	Drift and Niagaran limestone
Lake County—					
Lake Bluff.....	Village	498	56	52.5	Drift 181 feet; Niagaran limestone
Waukegan......	North Shore Gas Co.	145	[b]10	54.6	Drift 115 feet; Niagaran limestone
Waukegan......	North Shore Gas Co.	82	[b]6	54.2	Drift
La Salle County—					
Grand Ridge....	Village	160	110	53.2	Drift
Marseilles......	E. T. Hanshue	137	[b]2	53.6	St. Peter sandstone
Marseilles......	Crescent Paper Co.	128	[b]4	55.2	St. Peter sandstone
Mendota.......	C. B. & Q. R. R. Co.	480	[a]275	52.5	Drift, 136 feet; limestone, 305 feet; St. Peter sandstone
Wedron........	Sulphur Lick Spring	Spring	[b]1050	55.0	Temp. in pool; reported to be 52° as it issues from the St. Peter sandstone

[a] Air-lift equipment; all others have some form of deep-well pump.
[b] Flowing well or spring.

SHALLOW WELLS AND SPRINGS

The temperatures of the shallow-well waters at Downers Grove, Hinsdale, Naperville, Wheaton, and West Chicago are of interest (Table 5). These towns are located in a terminal morainic belt that has rather inadequate drainage. The heavy mantle of glacial drift acts as a collecting reservoir for the rainfall. Consequently the shallow wells yield large quantities of water. The temperatures range from 50° F. to 52.5° F., and this slight variation may be due to some heating as the water passed through the pumps. The normal annual temperature at these localities may be taken to be 48° F.; it is therefore seen that the coolest water is yet 2° F. warmer than the normal temperature.

These data were collected in July and August and the temperatures should therefore have been the lowest, if they were influenced by seasonal changes, because the effect of the annual variation in temperature proceeds so slowly downward from the surface that at depths of 30 or 40 feet the highest temperatures will be experienced in winter and the lowest in summer.[1]

GEOTHERMAL GRADIENTS IN GENERAL NORTHEASTERN ILLINOIS.

The geothermal gradient obtained from the preceding determinations of the temperatures of deep-well waters in northeastern Illinois is seen to be much lower than the normal. It is therefore advisable to state the factors which may affect the normal geothermal gradient and then consider them in relation to the conditions that exist in this area.

Factors Affecting Geothermal Gradients

There are a number of factors that tend to affect the normal geothermal gradient, among which the following cause a rapid increase of temperature:

1. Proximity to regions of recent eruptive rocks.
2. Regions of heat-producing waters, where the higher temperatures may be due to recent igneous activity or to exothermal chemical processes, as of decomposition.
3. Proximity to coal-bearing or highly carbonaceous strata.
4. Proximity to oil fields.
5. Existence in the vicinity of rocks containing oxidizable minerals.

The following factors have been regarded as having a tendency to lower the normal geothermal gradient:

1. High ridges and mountains.
2. Existence in the vicinity of large bodies of water.
3. Mines cooled by ventilation.
4. Very good circulation of underground waters.

It would therefore seem that the normal gradient should exist in regions of slight relief where the rocks are unaltered or not recent

[1] Milham, W. I., Textbook on Meteorology, page 106, 1912.

eruptives and where the especially modifying influences which have previously been mentioned, are absent.

Application to Northeastern Illinois

Northeastern Illinois has, as a whole, a gently undulating topography. The entire region is covered by a mantle of glacial drift whose geological age is comparatively recent. The maximum difference of elevation is about 600 feet. The lowest elevations are about 450 feet and are found along Illinois River; the highest areas are near 1,000 feet and occur along the Illinois-Wisconsin boundary line. The relief in any locality is rarely over 200 feet and is usually less. This region can therefore be considered as comparatively flat, and the modifying effects upon the geothermal gradient found in mountainous districts are here absent.

The geological succession is a series of magnesian limestone, shales, and sandstones. No coal-bearing strata are present in the greater part of the area; such rocks are found in LaSalle and Grundy counties, but the temperatures here are of waters from the underlying formations that are much older in age and contain no coal beds. Likewise most of the determinations were made on well waters in Chicago, at least forty miles from any coal-bearing strata. It is also to be noted that highly carbonaceous strata tend to increase the temperatures, whereas those obtained in Illinois are below the normal.

Summary

All the temperatures of deep-well waters in northeastern Illinois indicate a very low geothermal gradient. This is to be expected when the number of favorable factors that here exist are considered. The land has very little relief; no coal-bearing nor petroleum-producing strata are present. The formations are, for the most part, limestones and sandstones. Occasionally a small bit of pyrite may be found in the limestone, otherwise the rocks contain no oxidizable minerals. It is not thought that the cooling effect of Lake Michigan is of any great importance, as the low geothermal gradients are noted at distances of 50 miles from the lake.

WELLS

Dug or Open Wells

The dug wells are most commonly circular in shape, 3 to 5 feet in diameter, and from 20 to 50 feet in depth; the walls are generally lined with brick or planks. The water enters the well at the openings in the lining of the walls and at the bottom. The common practice is to discontinue the well when a sand or gravel stratum yielding a sufficient

supply of water has been penetrated. A few of the smaller towns have wells which are up to 20 feet in diameter, with the depths less than 30 feet. Wells of this type may be continued to the bed rock.

The chief objection to dug wells is the danger of pollution. The private wells are protected only by a plank top, in which cracks and other openings develop through warping, shrinkage, and other causes. Therefore surface water, carrying dirt from the shoes, domestic fowls, and other sources is washed into the well. The liquids from the barns, cesspools, and other outhouses seep into the ground and form a part of the underground waters. Therefore shallow wells in the vicinity of such buildings are subject to contamination. The water from such shallow wells has in many localities been the cause of serious epidemics of typhoid fever.

If dug wells are necessary, the coverings should be water tight, and a casing of the same character should be sunk into the ground as far as practicable. Pumps should be used in preference to the old-fashioned rope and bucket. No pools of foul or stagnant water should be permitted around any well.

Another disadvantage to most dug wells is the limited supply and fluctuation of the ground-water table. In times of drought when water is needed the most, these shallow wells frequently go dry. Deeper wells of smaller bore are more dependable.

Driven Wells

Driven wells are not common in this region. These wells consist of a pipe fitted with a porous section or "sand point", which is driven into sandy or unconsolidated material either by mallets wielded by hand, or by an apparatus somewhat similar to a pile driver.

Drilled Wells of Small Bore

GENERAL DESCRIPTION

Drilled wells are gradually supplanting dug wells and at the present time this is the prevalent type for small municipalities and the larger farms. Most of these are from four to eight inches in diameter at the surface, six inches being a common size, and the depth is from one to four or five hundred feet. These wells are drilled by the percussion method or churn drills by which the rock is broken up by the repeated blows of the drill suspended at the end of a cable. The drillings are removed at frequent intervals by lowering a sand pump or bailer. Most of these wells are drilled with a portable outfit in contrast to the "standard rig" used in drilling the larger wells. Over much of this area limestone

is the bed rock, and the drilled wells are cased to rock; then the drilling is continued with a hole of less diameter until a sufficient supply of water has been obtained.

Most of the wells that end in a sand or gravel bed in the drift are completely cased from the surface to the bottom. In some wells a screen is placed at the end of the casing, or the lower length of the pipe is perforated with a number of small holes.

COSTS OF DRILLING

The shallow rock wells are from 100 up to 400 or 500 feet in depth and are cased to bed rock. The cost depends primarily upon the depth and diameter of the hole. However, there is some variation in the prices charged by the different drillers. The table below probably represents the average cost, which includes ordinary iron pipe casing to rock, the contractor furnishing all necessary supplies and tools for drilling.

COSTS OF DRILLING SHALLOW ROCK WELLS

Diameter of hole	Price per foot[a]
3 inch	$1.25—$1.50
4 inch	1.50— 1.75
6 inch	2.00— 2.25

[a] Includes casing to bed rock.

Drilled Wells of Large Bore

DRILLING PROCESS

METHODS EMPLOYED

The deep artesian wells of Illinois are in general drilled by the percussion method. The rock is pounded to small bits by the repeated blows of a heavy drill or bit suspended by a cable or a number of wooden poles jointed together. This and other methods of drilling and the necessary apparatus are described in detail by Isaiah Bowman.[1] It will here suffice to mention only those phases of drilling and types of wells which are characteristic of this area.

Two types of "outfits," as all the necessary tools and other appliances for drilling are called, are in use. These are termed the *standard* and the *portable*. In using the standard outfit it is necessary to have a derrick, a pyramidal framework, 30 to 90 feet in height, erected over the well site. This derrick supports a crown block and pulley over which the cable passes in raising and lowering the tools. The portable outfit or "rig" is a modified form of the standard. The greater part of the drilling machinery is supported by a heavy framework usually mounted on wheels,

[1] Bowman, Isaiah. Well-drilling methods: U. S. Geol. Survey Water-Supply Paper No. 257, 1911.

in order that it may be moved from place to place by means of horses or a traction engine. The derrick is dispensed with, and instead a mast is used which can be collapsed and tilted back over the machinery when the outfit is being hauled.

The advantages of the portable outfit are its compactness, its easy removal after the completion of the well, and its elimination of the derrick. The standard outfit must be completely torn down and rebuilt for for each well. However, in general the portable outfits do not have the strength of the standard ones and are not adapted for so deep nor as heavy work.

The greater number of the deep wells in Illinois have been drilled with standard outfits, either cable or poles having been used. The pole method differs from the cable only in that the tools are supported by wooden rods instead of by cable or rope. The rods are from 2 to 3 inches in diameter. Each length of rod consists of two 18-foot pieces, spliced together and reinforced at the joints by irons. In drilling wells in this region most of the holes are full of water, which causes great friction on the rope cable. By using the wooden rods or poles the friction is greatly reduced, and the drilling proceeds more efficiently. Formerly most of the wells were drilled by the pole method, but at present this is being superseded by the use of steel cable because the increased size of hole necessitates the use of much heavier drilling tools.

Although most of the wells in this region have been drilled with the standard outfit, in the past two or three years some of the largest and deepest holes have been drilled with semi-portable outfits. A certain Chicago well contractor has had exceptionally notable success with the semi-portable outfit. A well at Aurora was drilled with one of these semi-portable outfits to a depth of 2,263 feet and completed with a diameter at the bottom of 15 inches.

DEPTH OF WELLS

The important artesian wells in this area range in depth from 500 to 2,700 feet. The average depth is influenced by the large number of wells in Chicago and vicinity which are about 1,600 feet in depth. It is very probable that the average depth of the important or large yielding wells in northeastern Illinois would be between 1,600 and 1,800 feet. The deepest well in this region, as far as could be learned, is one at Aurora which has a depth of 2,759 feet. Another deep drilling is the one at Streator with a depth of 2,496 feet. In the Stock Yards district at Chicago a number of wells have been drilled to depths greater than 2,200 feet and possibly over 2,500 feet, but no accurate data could be obtained in regard to these very old wells.

Most of the very deep wells were sunk for the purpose of obtaining an overflow at the surface. This was obtained in many places, but usually the resulting water had so high a mineral content that it could not be used for ordinary purposes. Many good wells have been ruined by continuing them to too great a depth and then encountering salt water. The belief is common that the deeper the hole the greater the yield; there is no greater fallacy. A greater head may be obtained at a greater depth, but not always an increased yield. The practice at present is to drill wells of larger diameters, as these have been found to give the increased yields.

CASING OF WELLS

The general type of artesian well in northeastern Illinois contains very little casing, as most of the strata are hard and do not cave. There is always a "drive" or surface pipe which extends through the drift to bed rock. In those localities where it is present the Maquoketa shale is usually cased off with a lighter pipe, although in numerous wells it was found to have been uncased. Occasionally some of the lower strata, as a zone below the St. Peter sandstone, will give a little trouble through caving. These are usually protected with a few lengths of casing. A few wells in this region have been cased completely to the water-bearing formations. Such wells are those at Proviso owned by the Chicago, North Western Railroad and the Chicago, Milwaukee & St. Paul Railway wells at Bensenville. The well owned by Mr. Moore at Lake Forest is of a similar type. The only well in Chicago having a large amount of casing is that of Sears Roebuck Company. In regard to the effect of these large amounts of casing upon quantity and quality of water obtained, the reader is referred to the more detailed discussions under the different localities.

SIZE OF WELLS

Naturally there is much variation in the diameters of the wells. As it is always necessary to reduce the size of the hole when any casing is placed, in order to leave a shoulder of rock for the pipe to rest upon, the wells are always smaller at the bottom than at the top. Then as the drilling is easier and progresses more rapidly with a small hole, the drillers prefer the lesser diameters unless the contracts specify otherwise.

Formerly the wells were much smaller in diameter, and if a large supply was desired the depth was made as great as possible, in many instances without giving an increased yield, or more wells were drilled. In late years it has been found that it is the wells of large diameter in in the water-bearing formations that give the great yields. Therefore such wells are being constructed. The wells drilled twenty years ago rarely had a surface diameter over 10 inches, and many of them were

only 6 or 8 inches; the bottom diameter would depend upon the depth and the number of lengths of casing that had to be placed. In many wells where the hole became not much over 3 inches in diameter the drilling with the old pole outfits became very difficult, as the wooden rods were almost the size of the hole. Most of the wells now drilled for the different municipalities and large industrial plants have a surface diameter between 12 and 16 inches and though rarely less than 6 inches at the bottom, they are more commonly 8 or 10 inches. The deepest well of a large diameter in this region is the 2,263-foot well at Aurora which has a diameter of 15 inches at the bottom. Other wells of large diameter are at Rockford, on the Ogden Armour estate at Lake Forest, and in the Chicago Stock Yards district. More data in regard to these wells can be obtained by referring to the discussion of the localities in which they are situated.

COSTS OF DRILLING

There is much greater variation in the drilling costs of the deep artesian wells than of those which barely penetrate the bed rock. The cost of drilling these deep wells is usually several thousand dollars, so that the common practice is to have a number of drilling contractors bid upon a well. Some of the factors which affect the cost of drilling are: character of strata, depth of well, diameter of hole at different parts, amount, size, and kind of casing, whether steam and light is furnished for drilling, whether a guarantee of a certain capacity is required, and whether a definite time of completion is specified. Also certain variations in costs are dependent upon supply and demand. If the contractors are all busy, they are not so likely to bid as low on new work as during times of less activity. A drilling firm with an idle drilling rig and with men that can be secured at low wages will bid lower than one not thus situated. Likewise drillers who are noted for rapid and successful completion of their work will obtain contracts at higher rates than will those who do not have this reputation.

DRILLERS' SPECIFICATIONS

The usual mode of procedure for a firm or municipality desirous of having a well drilled is to draw up a set of specifications, that states the different lengths of a certain size hole that are desired, amount, size, and kind of casing, and any other description that pertains to the type of well that is desired. Whenever possible it is best to have a competent supervising engineer or someone familiar with deep wells to decide upon the kind of well that will best serve the purposes for which it is desired. The specifications are sent to recognized drilling firms, and bids are usually received, with and without casing of a definite size, or the bid

may be a definite sum for the completion of the well according to specifications. A few typical specifications will be found on the following pages.

By another method the owner consults with a well contractor, stating that a well of about a certain capacity is desired. The driller determines from his experience the size of well required and names a definite sum for the completion of such a well. The driller may also give the price per foot for the lengths of a hole of a certain diameter, cased and uncased, a specification that enables the owner to compare with the prices of other contractors; this virtually amounts to bidding. The best plan is to have specifications made and then sealed bids received upon this basis.

The cost of a number of recently drilled wells in this area follows (Table 6). Requests have been made to withhold the names of certain drillers and owners.

TABLE 6.—*Drilling costs of representative deep wells*

Locality	Owner	Date drilled	Depth	Amount and diameter of casing: Length	Amount and diameter of casing: Diameter	Diameter of well at bottom	Average cost per foot	Total cost	Steam for drilling furnished by;	Remarks
Cook County—			*Feet*	*Feet*	*In.*	*Inches*				
Bellewood....	Village	1913	1538	87 201 62	12 10 8	7½	$2.95	$ 4,748.86	Driller	Total cost includes $2.00 for a 100-hour test
Berwyn......	Village	1912	1605	36 200	16 10	7½	2.69	4,320.00	Village	No other casing mentioned, but probably some 8 in.
Chicago......	Confidential	1912	1650±	76 150 45	12 10 8	7½	4.00	6,600±	Owner	The 8-in. casing is for the "cave" at 1,000± feet
Chicago......	Confidential	1912	1650±	68 160 105	16 10 8	7½	4.50	7,425±	Driller	
Chicago......	Confidential	1913	1625±	83	12	7½	3.40	5,500±	Owner	Maquoketa shale and "cave" probably cased off, although not mentioned
Chicago......	Confidential	1913	1675±	80	12	5½ or 7½	1.50	2,500±	Owner	Probably no casing for Maquoketa shale and "cave"
Chicago......	Confidential	1913	1625±	44 275 60	10 6 5	4½	2.00	3,250±	Owner	The 5-in. casing is for "cave" at 1,000± feet
Chicago......	Confidential	1914	1650±	70 125 60	12 10 8	7½	2.00	3,300±	Owner	It is possible that the owner bought the casing separately
Chicago......	Confidential	1914	1625±	65 250 50	16 10 8	7½	3.00	5,000±	Owner	Owner demanded guarantee of 500 gallons and other rather stringent requirements
Chicago......	Confidential	1914	1950±	56 535 60	10 6 5 3/16	4¾	2.25	4,400±	Owner	
Chicago......	Confidential	1914	1600	50±	12	7½	2.00	3,200±	Owner	Not known whether shale and "cave" were cased off

TABLE 6—*Concluded*

Locality	Owner	Date drilled	Depth	Amount and diameter of casing: *Length feet*	Amount and diameter of casing: *Diameter feet*	Diameter of well at bottom	Average cost per foot	Total cost	Steam for drilling furnished by;	Remarks
Chicago......	Confidential	1914	1875	45 130 30	12 10 8	7½	3.50	6,560±	Driller	
De Kalb County										
De Kalb.....	City	1912	1306	156 113 101	16 10 8	7½	3.56	4,652.91	Driller	The 15-in. hole extends to a depth of 250 feet
Sycamore....	De Kalb and Sycamore Electric R. R. Co.	1914	1002	143	12	6	2.65	2,650	Driller (?)	May be other casing, but not mentioned
Grundy County-										
Morris.......	City	1915	720	82 335	20 16	12	6.84	4,927	Driller (?)	
Kane County—										
Aurora......	City	1915	2263	31 255	21 18	15	8.92	20,280.67	Driller	The deepest well of this large size in northeastern Illinois
Batavia......	City	1915	2002	42 77	12 8	7½	3.70	7,480	City (?)	
Confidential..	Confidential	1914	1840±	39 100	16 8	7½	3.43	6,320±	Owner (?)	
La Salle County										
Grand Ridge.	Village	1914	160	160	10	10	3.55	568	Driller	Drilling stopped at a sand and gravel bed in the drift
Oglesby......	City	1915	1645	88 338 260 448	18 15 10 8	7½	4.03	6,627	Driller	Completely cased through "Coal Measures" from surface to a depth of 880 feet

SPECIFICATIONS

FOR ARTESIAN WELL TO BE DRILLED AND EQUIPPED FOR........................ COMPANY, A CORPORATION HEREINAFTER CALLED THE OWNER

Size, Depth and Casing of Well.—A hole about 18″ in diameter is to be drilled from the surface of the ground to a water tight connection into the rock at whatever distance below the surface located, and same is to be cased off with 18″ outside diameter pipe ⅜″ thick, butted joints, extra heavy couplings extending from the surface of the ground to a watertight connection with the rock at whatever distance below the surface located. For convenience in construction, the contractor may make the casing as much larger than 18″ O. D. as he may desire. This casing shall be standard well casing having not less than ⅜″ inch wall, with couplings of ample strength fitted in all respects for the purpose used.

The lower end of the casing shall be fitted with a suitable steel shoe, and the casing shall penetrate the rock a sufficient distance to produce a tight connection between the casing and the rock, so that all sand, mud, gravel or surface water will be shut off from the well. From the lower end of this casing to a point 250 feet below the surface of the ground a 17⅛″ hole is to be bored. From this point a 12″ hole is to be extended down through and past the shale, and the shale through its entire length, lapping 4 feet above top of shale, is to be cased off with 10″ standard wrought iron pipe. From this point a 10″ hole is to be extended down through the formation known as the cave, which will be a point approximately 1,000 feet from the surface of the ground. This caving rock is to be cased off through its entire length with 8″ standard wrought iron pipe. From this point an 8″ hole is to be extended down through the rock to a point 1,650 feet from the surface of the ground, or to be continued down to a depth anywhere between 1,650 foot level to a depth 2,000 feet, at the option of the owner.

Should any further casing be necessary other than that specified above to insure the permanency of this well, the Contractor is to install same without additional cost to owner, and in no instance is the outside diameter of the standard wrought iron pipe to be less than the diameter of the hole in which same is inserted.

Drilling.—The Contractor shall furnish all derricks, engines, tools and machinery of whatever description that are necessary to construct and complete the well.

Alignment.—It is intended that a pump casing with a diameter as large as is practicable shall be admitted in that part of the bore which is 17⅛ inches in diameter, which pump may be lowered to any point below the water level down to the bottom of the 17⅛″ hole, and before the well shall be accepted, the Contractor shall demonstrate that the alignment and bore of this hole is sufficiently straight in concentric to accommodate said pump.

In order that this fact may be demonstrated, the Contractor shall, at his own expense, make the following tests:

A dummy shall be constructed 20 feet in length, have three (3) rings, each ring 12 inches wide and 16⅝ inches outside diameter. The rings shall be truly cylindrical and shall be spaced one at each end of the dummy and one ring in the center thereof. The spokes of the rings shall be at right angles to the vertical axis of the dummy. This dummy shall be lowered into the well and shall move freely without binding, to a depth of two hundred and

fifty (250) feet below the surface. Should the dummy fail to move freely throughout this entire length, the alignment of the well shall be corrected by the Contractor at his own expense, or should he fail to correct the alignment, a new well shall be constructed at a point to be designated by the Owner, without additional expense to the Owner.

Samples and Records.—The Contractor shall keep an accurate record of the location of the top and bottom of each strata penetrated, and shall save and deliver to the Owner a sample of material from every 10 feet of drilling, which same shall be enclosed in a suitable wide mouthed bottle, plainly labeled with the depth of the top and bottom of said stratum. Bottles will be furnished by the Owner.

The contractor shall collect and deliver to the Owner samples of clear water for the purpose of analysis at such times as may be designated by the Owner throughout the construction of the well.

Measurements.—To determine the depth of the various sized holes the Contractor is to verify measurements of the holes with the Engineer representing the Owner, and as soon as a particular sized hole is completed, he is not to start on next size smaller until both he and the Engineer have agreed as to the depth of same.

Steam, Water, and Light.—The Owner will permit free use to Contractor of Owner's steam, water and electric light, and will make the necessary steam connections from boiler to Contractor's engine at Owner's expense.

Debris from Well.—Contractor is to construct a box into which the cuttings from the well shall be dumped, and Owner will cart same from the premises and will provide an outlet for the water which is dumped from the well.

Guarantee and Tests.—The Contractor guarantees, without reservations or understandings not expressly mentioned in these specifications, that the well will furnish five hundred (500) gallons of water per minute.

In order to demonstrate the fulfillment of this guarantee, the Owner will, at its own expense, use a standard type of air lift, similar to Harris, Pohle, or Weber, at its own option.

The air pressure for this test to be not over 175 pounds to start the well; the size of air pipe to be 2 inches. Submerging of air pipe to be within the limit of the 175 pounds pressure.

The method of measurement to be weir and notch with hook gauge. Compressed air is to be furnished at the well from the air compressor furnished by the Owner.

The Owner reserves the right to make the final test a continuous test extending over 15 days. To fulfill the guarantee the well must discharge 500 gallons of water per minute during the entire period of fifteen days continuously.

In case the guarantee is not fulfilled by the above test, the Contractor reserves the right to make a test at its own expense with a deep well pump. This test to extend continuously for 48 hours; water to be measured same as in test with air.

The tests mentioned to be made when the well has reached a depth of 1,650 feet from the ground. If the well fulfills the guarantee at the depth of 1,650 feet, then the drilling shall cease; if the well does not fulfill the guarantee at that depth, the Contractor shall continue to drill to a depth of 1,850 feet, at which depth another set of tests are to be made same as specified

above. If the well fulfills the guarantee at the depth of 1,850 feet, the drilling shall cease; if the well does not fulfill the guarantee at the depth of 1,850 feet, the Contractor is to continue to drill to a depth of 2,000 feet, at which depth another set of tests are to be made, same as specified above. If the well does not fulfill the guarantee at the depth of 2,000 feet, then the Contractor may, at its option, drill to a depth of 2,500 feet, at which depth another set of tests are to be made, same as specified above.

In order that the Owner may know when to make the said tests, the Contractor shall in writing notify the Owner when each of the depths specified for the making of the tests has been reached. Should the Contractor elect to make the tests, which the Contractor has reserved the right to make, he shall in writing notify the Owner of the time when the making of the tests is to begin, to the end that the Owner may have its representative present.

The Owner is to be put to no expense in making the tests for the use of tools or apparatus of any kind belonging to Contractor, or for the time of Contractor's men, such being the intent and purpose of this contract and specifications.

PROPOSALS, SPECIFICATIONS, AND CONTRACT FOR THE SINKING OF A WELL, TO BE CONNECTED WITH THE MUNICIPAL PLANT OF THE CITY OF BATAVIA, ILLINOIS

Sealed proposals will be received at the office of the City Clerk of City of Batavia, Kane County, Illinois, until five o'clock P. M., Monday, July 27th, 1914, for the drilling, casing and connecting with the pumping pit of the Municipal Plant of the City of Batavia, Kane County, Illinois, of an artesian well.

LOCATION

The well is to be located on the north east corner of sub lot B. of block 5 of the Island Addition to the City of Batavia, Illinois, as shown by plat thereof on file in the Recorder's office of the County of Kane. Provided, however, this location may be changed by the direction of the Committee on Fire and Water of the City Council of the City of Batavia, Illinois.

IN GENERAL

Bidders will make an examination of the premises and make themselves familiar with any difficulties that may be foreseen.

Specifications, contract and proposal blanks can be had on application at the office of the City Clerk.

All bids must be accompanied by a certified check, equal to ten per cent of the amount of the bid for the total of items, 1, 2, 3 and 4 of the proposal, made payable to the City of Batavia, as a guarantee that if the bid is accepted, contract will be entered into within ten days from the acceptance of the same.

Proposals must be made on the blanks furnished by the City of Batavia. The City Council reserves the right to reject any or all bids or to waive any informality which may be for the benefit of said city.

W. H. Reaney, City Clerk.

Authorized by the City Council of the City of Batavia, Illinois.

SPECIFICATIONS FOR THE SINKING OF A WELL FOR THE CITY OF BATAVIA, KANE COUNTY, ILLINOIS

Hereinafter the City of Batavia, Illinois, will be known and referred to as the Owner; the person, firm or corporation that is to furnish the materials, apparatus, appliances and labor, as the Contractor; and when the term Engineer is used herein, it shall refer to L. A. Parre, Superintendent of the Municipal Plant of the City of Batavia, Kane County, Illinois.

The Contractor will be held to execute such work and to use such materials and to perform such other duties as are hereinafter described, and all parts and portions of the completed installation must present a workmanlike piece of work and be in a thoroughly first-class operating condition.

The Engineer shall have the privilege and shall be afforded every opportunity for properly inspecting the materials, appliances, apparatus and appurtenances and the condition of the well in the passing through the different strata of rock or other formation.

The Owner reserves the right to alter or modify the specifications or to add to or deduct form the contract price without rendering the original contract void.

In case of alteration in the specifications, an addition to or a deduction from the contract price shall be made in proportion as such labor and materials necessary to the accomplishment of said alteration is to the amount of labor and materials contracted for, but no alteration is to be made or extra work done for which a charge will be approved or a credit allowed unless a price for same be agreed upon beforehand and the amount endorsed upon the original contract or set forth in a written instrument executed by the Engineer, and in case no agreement can be effected between the Owner and the Contractor as to the price to be paid for such alteration or extra work, the decision of the Engineer to be binding and conclusive.

The interpretation or explanation of these specifications obtained from any other source than the Engineer will not be accepted as binding, and his report and decision is binding and conclusive.

Before submitting a tender, the Contractor shall visit the premises and make a thorough and careful examination to familiarize himself with all conditions existing, and in awarding the contract, it will be assumed that such action has been taken.

The work must be commenced within such time from the date of the execution of the contract as shall be set forth in said contract, and shall be prosecuted uninterruptedly and with a sufficient force to insure the speedy completion of all parts and portions thereof.

The Contractor must put himself in communication with the Engineer and arrange the prosecution of the work to be performed by him so as not to unnecessarily hinder or delay the prosecution of any work being performed by or for the said Owner.

The Contractor is to use such methods and appliances for the performance of all work embraced under this contract as will secure a satisfactory quality of work and a rate of progress which, in the judgment of the Engineer, will secure the completion of the work within the time limit specified in the contract.

The Contractor will be required to furnish a good and sufficient bond, acceptable to the Owner, to insure the faithful performance of the obligations

set forth in the contract and these specifications, including the payment of laborers and mechanics for labor.

The Contractor shall not be entitled to any claim for damages, for any hindrance or delay from any source or cause whatsoever in the progress of the work or any portion thereof, but such hindrance will entitle the Contractor to such extension of time for completing the contract as may be determined by the Engineer, provided the Engineer be given notice in writing at the time of such hindrance or the cause of detention.

The Contractor must sustain all losses and damages arising from the action of the elements, flood waters, or the nature of the work to be done under these specifications, and he will be held responsible for any and all material or work to the full amount of the payments made thereon and he will be required to make good at his own cost any injury or damage which the said materials or work may sustain from any source or cause whatsoever before the final acceptance thereof.

The Contractor shall indemnify and save harmless the said Owner or its officers or agents from any and all claims for renumeration or indemnity for or on account of any injury or damage to person or property received or sustained by any person or persons, firm or corporation, by or from the said Contractor or by or in consequence of any materials or explosives used in or around or upon the said work, or by or on account of any improper material or workmanship used or employed in the construction, or by or on account of any accident or any act or omission of the said Contractor or his agents or servants or employes, and so much of the money that is due or to become due the Contractor under his contract as shall be considered necessary by the Engineer may be retained by the Owner until such suits or claims for damages or otherwise as aforesaid, shall have been finally determined and settled, and evidence to that effect furnished to the satisfaction of the Owner and Engineer.

Defective materials may be condemned by the Engineer and when so condemned shall be destroyed or removed and shall not be used by the Contractor on any part of the work. In case of failure to remove or destroy such condemned materials, after written notice has been served by the Engineer, within the time specified in said notice, the Engineer may cause the said condemned materials to be destroyed or removed and acceptable materials substituted therefore. The cost of such substituted material and the cost of removing or destroying said condemned materials, shall be deducted from any amounts due or to become due the said Contractor.

The Contractor shall strictly observe and comply with any and all Ordinances of the city and statutes of the State in which the work herein provided for is to be performed, and shall obtain any or all permits, inspections and otherwise, which shall be necessary or required for the conduct of such work or the placing of the completed work in operation or service.

The Contractor shall not use any patented device in connection with any part or portion of the work herein provided for without the written consent of the patentee first had and obtained, and the execution of the contract by the Contractor shall constitute a written guarantee, protecting the said Owner on account of any suit, action or proceeding brought in any court for infringement of patent or patents on any part or portion of the work herein provided for.

The Contractor shall, at his own expense, defend by good and competent attorneys any and all suits, actions or proceedings brought against said

Owner, or any or all of its officers or agents, due to any of the causes set forth in these specifications, and shall pay any and all judgments that may be rendered therein without calling upon the Owner or any or all of its officers or agents for the same or any part thereof.

SIZE AND CASING OF CAVES

The well is to be twelve inches in diameter from the surface of the ground to such point in the rock as solid uniform rock shall be found in which a twelve-inch casing is to be thoroughly packed, from the bottom of said casing, which is where the solid uniform rock as aforesaid has been encountered, to the bottom of the well a hole twelve inches in diameter shall be drilled, provided however, if a cave be encountered at or below 900 feet, the Contractor may case off the cave in a proper manner and satisfactory to the Engineer, and from this said cave so encountered, shall continue the well to the bottom at a diameter of not less than eight inches provided further, that if a second cave be encountered at or below 1500 feet, the Contractor may case off such cave so encountered, in a proper manner and satisfactory to the Engineer, and from there continue the well to the bottom of a diameter of not less than seven inches. The well shall not be less than seven inches in diameter at any point from 1500 feet to 2200 feet in depth, and not less than eight inches in diameter at any point from 900 feet to 1500 feet in depth, not less than ten inches in diameter at any point above 900 feet in depth.

DRILLING

The Contractor shall furnish all tools, materials, appliances, labor and the necessary 12-inch, 10-inch, 8-inch and 7-inch galvanized, full weight pipe for casing, required for the prosecution of the work in accordance with these specifications, and testing of the well at its completion in accordance with these specifications.

PRESERVATION OF SAMPLES

The Contractor on sinking the well shall preserve samples of the material or strata encountered, in the manner hereinafter described.

Samples of Materials shall be taken at each ten feet in depth of the well and also at each and every point where a variation in the strata from the last sample taken may be observable.

Each sample of said material shall be placed in a one pint glass fruit jar to be furnished by the Owner and labeled by the Contractor with the depth from the surface of the well, at which the sample was taken.

Samples obtained during each twenty-four hours shall be delivered to the Owner, represented by the City Clerk, or the Engineer on or before twelve o'clock noon of each day during the continuance of the work, and the Contractor shall receive a receipt for said samples so delivered, said receipt shall show the number of samples taken during the previous twenty-four hours and the depts at which each sample was taken. The preservation of these samples is considered an essential point in the execution of the contract and failure to properly fulfill these specifications shall be considered as definite damage to the Owner for which they shall be entitled to retain from the contract price for the work of sinking the well the sum of Five

Dollars ($5.00) for each sample which the said contractor shall fail to preserve and deliver as above described. The receipts given for and upon the delivery of the samples shall be taken as a check on the number of feet sunk in the drilling of the well.

CASING

The casing above referred to shall extend down to the solid rock and shall be twelve inches nominal inside diameter and twelve and 80-100 inches outside diameter, full weight galvanized. Said casing shall be of the best lap welded charcoal refined iron and shall be made with flush joints and shall be packed in said rock at the depth specified in a manner approved by the Engineer.

LIMIT OF DEPTH

At any point where a flow of water is encountered large enough to warrant the Owner in the belief that it will be sufficient for the desired water supply the Owner shall have the right to discontinue the work on said well and the test hereinafter described may then be made.

If the test is not satisfactory and the Owner may so direct, the drilling shall be continued to further depths and so on until the maximum depth herein specified shall be reached, at which time the drilling thereof may be ordered discontinued by the Owner.

The Owner reserves the right to discontinue the sinking of the well at any depth below 900 feet which shows upon test that in the opinion of the Owner and the Engineer the flow of water is sufficient for the desired water supply and the quality of the water is approved.

TESTS

At any point wherein a flow of water is struck which appears to be sufficient for the necessary water supply the Contractor shall make the following tests of the well.

The well shall be piped to various heights and the point to which water will run in said pipe shall be accurately determined.

At any point in said pipe at a height which the Owner may direct a Tee shall be inserted in the said pipe and a test of the flow of said well made by running the water through said Tee over a weir or into a tank to be provided by the Owner and the amount of water flowing be determined.

This measurement may be repeated at from two to eight different heights as the Engineer may direct.

If the Owner shall so direct the following test shall also be made.

This test shall be made by means of a two-inch wrought iron pipe of suitable length, which shall be packed off just above the water bearing strata and at various heights above said strata, not to exceed ten in number, which the Owner may select. Said two-inch wrought iron pipe shall be joined together by water tight sleeve couplings and shall be of such length as to reach from the point at which the pipe is to be packed to the surface so that the variation in head if any, due to the packing off of the pipe at such depth may be noted, the packing to be at the lower end of such two-inch pipe and to be made by means of a double bag of heavy canvas or leather filled with flaxseed or such other packing as the Contractor may select, which

will thoroughly accomplish the same purpose, to the satisfaction of the Owner and the Engineer.

During the making of any test of the flow of water, should the difference in pressure between the heights of two testing spots show a leakage in the well, the well shall be cased off to prevent such leakage and the test again applied.

At any and all depths where a test of the flow of the water is made, samples of the water shall be taken and placed in receptacles furnished by the Illinois Water Survey, said samples so taken shall be forwarded to the State Water Survey for their examination and should the result of their analysis show that there is an excess of salt, sulphur or other mineral of an objectionable nature, the well shall be cased off to prevent said water, so objected to, from entering the well, the expense of said casing off shall be borne by the Contractor.

TILE

All the tile used in the construction of the connection between the pumping pit and well shall be of the best quality vitrified, salt glazed tile, well burned throughout their thickness, the body of the pipe to have a uniform thickness of 1⅜ inches. All tile having fire cracks, blisters and iron pimples, which the Engineer shall deem injurious, will be rejected. All hubs and sockets must be of sufficient diameter to receive, to their full length, the spigot end of the following pipe, without any chipping whatever of either and to leave a space of not less than ¼ inch in width all around for the cement mortar joints, the joints will be made by tightly pressing cement mortar to the full depth of the joint, the ends of the tile are to abut close against each other in such manner that there shall be no shoulder or want of uniformity of surface on the interior of the tiles, the joints are to be as uniform as possible in thickness and thoroughly filled with mortar, each joint is to be wiped clean of mortar on the inside before another length of tile is laid.

All cement for filling the joints shall be pure fresh ground Louisville, Utica or other equally as good cement of best quality, with only enough water added to give it the proper consistency and shall be mixed only as needed for use, one part cement by measure and two parts by measure of clear sharp sand.

The trench when excavated for the tile shall be deep enough so that the top edge of the tile shall be at least twelve inches below the surface of the ground.

CONNECTIONS

Upon completion of the well as herein described the Contractor shall furnish one twelve-inch cast iron Tee, flanged pattern with companion flanges for two branches of said Tee, also one twelve-inch gate valve.

The Contractor shall guarantee the completed work to be complete in every detail and free from defective materials and imperfect workmanship and to be in all respects in accordance with these specifications.

In awarding this contract consideration will be given the following.

1st. Time of completion.

2nd. Ability and reliability of Contractor as shown in previous endeavors in this line of work.

3rd. Price per foot at the various depths.

4th. Price of materials to be furnished.

To the Mayor and City Council of the City of Batavia, Illinois:

The undersigned having examined the specifications and premises, herewith present proposals as follows:

ITEM		
1	For the furnishing of approximately 40 feet of twelve-inch casing, one twelve-inch tee, one twelve-inch gate valve with companion flange, one twelve-inch nipple, approximately 40 feet vitrified salt glazed tile and connecting well with the pumping pit of the Municipal Plant of the City of Batavia.......................................$	....
2	For the sinking of the well 900 feet, price per foot........	....
	Estimated time required for same, days................	
3	For the sinking of the well from 900 feet to 1,200 feet, price per foot..	....
	Estimated time required for same, days................	
4	For the sinking of the well from 1200 feet to 1500 feet, price per foot..	....
	Estimated time required for same, days................	
5	For the sinking of the well from 1500 feet to 1800 feet, price per foot..	....
	Estimated time required for same, days................	
6	For the sinking of the well from 1800 feet to 2200 feet, price per foot..	....
	Estimated time required for same, days................	
7	For the sinking of the well below 2200 feet, price per foot	....

Respectfully submitted,

....

By..

Certified check, inclosed, $.............

This Agreement, made this................day of...................... A. D. 1914, between the City of Batavia, Illinois, party of the first part and .... of the City of Batavia, State of Illinois, party of the second part.

Witnesseth, that for and in consideration of the agreement and covenants hereinafter contained on the part of the first party, the party of the second part hereby agrees to sink a well for the said first party according to and in all respects in compliance with the proposal and specifications heretofore attached.

The second party agrees to commence within twenty days from the signing of this contract upon the actual drilling and sinking of the well and to within twenty days from the signing of this contract place themselves and their machinery in such a position that they will be well equipped and able to commence such actual drilling not later than at the expiration of the said twenty days from the signing of this contract.

The said second party further agrees that in every respect they will complete the sinking of the well referred to in this contract within such time as follows:

If the well shall be nine hundred feet or less, within.................. days from the commencement of the actual drilling of the same.

If the well shall be more than nine hundred feet and twelve hundred feet or less, within................days from the commencement of the actual drilling of the same.

If the well shall be more than twelve hundred feet and fifteen hundred feet or less, within................days from the commencement of the actual drilling of the same.

If the well shall be more than fifteen hundred feet and eighteen hundred feet or less, within................days from the commencement of the actual drilling of the same.

If the well shall be more than eighteen hundred feet and twenty-two hundred feet or less, within................days from the commencement of the actual drilling of the same.

If the well shall be more than twenty-two hundred feet within............. days from the commencement of the actual drilling of the same.

The said first party agrees that for and in consideration of the performance of the covenants of the said second party and for the satisfactory performance of their work in accordance with the specifications attached hereto agree to pay to the said second party the following amount: For the furnishing of approximately 40 feet of twelve-inch casing, one twelve-inch tee, one twelve-inch gate valve with companion flange, one twelve-inch nipple, approximately 40 feet vitrified salt glazed tile, sinking of the well the first nine hundred feet, and connecting well with the pumping pit of the Municipal Plant of the City of Batavia,..
.... Dollars

For the next three hundred feet....................................Per foot

For the next three hundred feet....................................Per foot

For the next three hundred feet....................................Per foot

For the next four hundred feet....................................Per foot

Below twenty-two hundred feet....................................Per foot

The payment for the sinking of the said well shall be made in the following manner at the expiration of every two weeks from the commencing of the actual drilling of the well. The said first party shall pay to the said second party seventy-five per cent of the amount which is at such times due and unpaid, and such payments shall be made in accordance with and upon the issuing of the certificate by the Engineer of the City of Batavia, which certificate shall set forth the depth which has been reached at the time of the issuance thereof.

It is further agreed between the parties hereto that the remaining twenty-five per cent of the amount due and unpaid in accordance with the above paragraph shall be paid to the second party upon the certificate of the Engineer that the well has been completed and tested and recommending the acceptance of same by the Owner.

It is further agreed between the parties hereto that the proposals and specifications hereto attached shall be made and considered a part of this contract as fully as though the same were printed in the body hereof over the signatures

and seals of the parties hereto, and where any questions of any nature arises under this contract or in reference to the same, the proposals and specifications hereto attached shall have the same force and effect as though they were written or printed in the body of this contract.

In Testimony Whereof, the party of the first part has caused these presents to be signed in its behalf by its Mayor, and its Corporate Seal to be hereto affixed, attested by its City Clerk, and the parties of the second part have hereunto set their hands and seals, the day and year first above written.

City of Batavia,

By................................

Mayor.

Attest to Seal

....

City Clerk.

....[SEAL]

....[SEAL]

....[SEAL]

PUMPING OF WELLS

METHODS

Deep-well pumps.—The municipal wells of the smaller towns and at many of the industrial plants are equipped with the rod-and-plunger displacement, commonly called "deep-well pump." These pumps are generally used where the lift does not exceed 150 feet and the desired yield is not over 100 gallons per minute. Most of the smaller pumps of this type are single-acting, but the larger, newer ones are double-acting or of the continuous-flow class. The small, common deep-well pump that is used in factories is the "steam pump"; in this type the steam and water cylinders are placed on the same machine.

Many of the larger, double-acting, deep-well pumps, which have capacities up to and over 250 gallons per minute, are motor driven. The following towns are a few of those in this area that are equipped with large, motor-driven, deep-well pumps: Park Ridge, De Kalb, Morris, Minooka, Lemont, Lyons, and Grand Ridge.

Impeller or centrifugal pumps.—This class includes the centrifugal or as it is sometimes called the "turbine pump." The water is raised by the energy transmitted to it through the rapid rotation of curved vanes in an enclosed chamber. In a common type of this pump the chamber or "stage," as it is called, is beneath the water level, and the axis to which the vanes are attached, extends to the surface. Then the entire axis is rotated rapidly by some motive power applied at the surface, and the water is thus elevated. Where the lifts are large, it is usual to have a

number of stages in order to transmit sufficient velocity to the water to send it to the surface. The centrifugal pump is used in a number of the municipal pumping plants in this locality; as a rule it has been found very satisfactory with lifts not over 150 feet. This form of pump is operating against a very high lift, in one of the city wells at Aurora where a 4-stage, 17-inch turbine pump is placed at a depth of 201 feet and at times it is necessary to raise the water against this entire head. The following municipal plants are equipped with one form or another of the centrifugal pump: Rockford, Aurora, Batavia, LaGrange, Forest Park, and Chicago Heights.

Air-lift pumps.—The air-lift is a device by means of which the water is raised from a well through the action of compressed air. The pumping equipment consists of an air compressor at the surface, an air-receiver tank to regulate the amount and pressure of air from the compressor, a large pipe in the well for the discharge of the water called the "eduction pipe," and an air pipe to convey the compressed air to the bottom of the eduction pipe. The air pipe may be placed within the eduction pipe, the water thus occupying the space between the two. Another method is where the air pipe is placed along side the eduction pipe, the air being conveyed to the eduction pipe at its bottom. The latter arrangement is the one more commonly in use, although where the well is not of sufficient diameter to contain two pipes of the necessary sizes the air pipe is placed within the eduction. In some places the bottom of the air pipe is equipped with what is called a foot-piece or nozzle. The foot-piece is supposed to give the air lift a greater capacity.

The reader is referred to a bulletin of the University of Wisconsin which treats of an investigation of the air-lift made by Davis and Weidner.[1] This is an excellent treatise on the subject derived from tests obtained on a small air lift, the maximum lift being about 24 feet, in the University Engineering Laboratories. The bulletin contains also a very good bibliography concerning the air-lift pump.

The authors recognize five variables which may affect a particular type and size of pump; these are: (1) percentage of submergence, (2) lift, (3) discharge, (4) volume of air, (5) pressure of air. The conclusions reached are given below. These conclusions have been somewhat questioned by certain manufacturers of air-lift equipment as not being entirely applicable to large wells with lifts of over 200 feet; they say that the experimental pumping plant at Wisconsin was too small and did not represent actual conditions in large wells. In all justice to the authors it should be stated that they say that the conclusions will hold

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[1] Davis, Geo. J., and Weidner, C. R. An investigation of the air-lift pump: Bull. of the University of Wisconsin No. 450, Eng. Series vol. 6, No. 7, pp. 405-573, 1911

only for the particular type, size, and length of pump in which the experiments were performed. They infer, however, that the conclusions will hold for other types and sizes. These inferences, on the whole, the writer believes to be correct.

The conclusions are:

1. The central air-tube pump has the greatest theoretical capacity for a given size of well.

2. The coefficient of pipe friction and slip decreases as the discharge increases, and decreases as the ratio of volume of air to volume of water increases.

3. The coefficient of pipe friction and of slip varies with the length of pump, but it seems to be independent of the percentage of submergence and of the lift.

4. The length of pump, the percentage of submergence, and therefore the lift remaining constant, there is a definite quantity of air causing the maximum discharge. This quantity of air for maximum discharge, as also the ratio of volume of air to volume of water, differs for different percentages of submergence and lift, the length of the pump remaining constant.

5. The length of pump remaining constant, the maximum output occurs at about the same percentage of submergence for all rates of air consumption, being at from 61 to 65 per cent for the pump used in the Wisconsin experiments. At other submergences the output varies as the ordinates of a parabola having a vertical axis. Under these conditions the lift does not remain constant as the percentage of submergence varies.

6. The length of pump and percentage of submergence remaining constant, and therefore constant lift, the efficiency increases as the input decreases; that is, the highest efficiencies are obtained at the lowest rates of pumping.

7. By varying the percentage of submergence, and therefore the lift, the length of pump remaining constant, the maximum efficiency is obtained at approximately 63 per cent submergence for all rates of input or discharge.

8. The lift remaining constant, the efficiency increases as the percentage of submergence increases, for all rates of input and all practical percentages of submergence.

9. With the same size and type of pump, the percentage of submergence remaining constant, the efficiency increased as the lift increased for the small lifts experimented on; that is, up to about 24 feet. From a theoretical study, however, the indications are that a point will be reached from which the efficiency will decrease as the lift increases.

10. Other conditions remaining constant, there is no advantage to be gained by introducing compressed air above the surface of the water in the well.

11. The type of the foot-piece has very little effect on the efficiency of the pump, so long as the air is introduced in an efficient manner, and the full cross-sectional area of the education pipe is realized for the passage of the liquid. Any thing in the shape of a nozzle to increase the kinetic energy of the air is detrimental.

12. A diverging outlet which will conserve the kinetic energy of the velocity head increases the efficiency.

The percentage of submergence is that per cent of the total length of pipe between the discharge of the water at the surface and the lowest entrance of air into the eduction pipe in the well, which is submerged. If the discharge pipe does not extend below the lowest entrance of air into it, the percentage of submergence is the per cent of the length of the discharge pipe which is submerged. The amount of submergence used in the air-lift pumps varies, although about 60 per cent is the amount that is used in practically all efficient equipments. In a number of cases where the air compressor's capacity is not great enough to permit this amount of submergence, the length of air pipe is not so great. Some wells that are subject to a great lowering of the water level on pumping, as wells of small bore at the bottom, are equipped with auxiliary air lines to permit the initial head to be pumped off at lower pressures. By these means it is possible to secure a greater submergence and yet not require any higher air pressure than that required, under operating conditions. There is no doubt but that use of these auxiliary air lines is an advantage and many of the smaller installations would have a greater efficiency by making such changes. This would give a better submergence and utilize to the greatest extent the possibilities of the small air compressor.

The increased size of the eduction pipe toward the outlet is another means of increased efficiency that is used in some cases and should be used to a greater extent.

The conditions are rarely the same in any two wells, and therefore a very satisfactory air-lift equipment for one well might not be at all applicable to another. Each well is a problem in itself. Therefore before the installation of any permanent pumping equipment, sufficient tests should be made under the direction of a competent engineer to determine what arrangements of the different lengths and sizes of pipe are most efficient. Even a very good air-lift may become antiquated by a lowering of the water level or by changes in the rate of pumping.

The air-lift is used to a greater extent in this area than any other pumping arrangement where it is necessary to raise large quantities against a great head. It is by far the most important pumping equipment in Chicago and vicinity, where the head pumped against is in many instances over 230 feet. The air-lift has commonly not been considered very efficient, although some of the larger installations in the Chicago Stock Yards district have obtained very satisfactory results. The flexibility of the air-lift and the lack of repairs required are reasons why it is in such wide use. No other pumping method is probably capable of raising larger quantities of water from a bore-hole with such high lifts as encountered around Chicago.

COSTS OF PUMPING

General considerations.—So many factors affect the cost of deep-well pumping that it is very difficult to make comparisons between the different installations. Merely because a certain pumping equipment is able to deliver water at a lower cost per thousand gallons does not necessarily mean that it is more efficient than another where the cost is greater. Much depends upon the amount of water available, height to be raised, cost of power, and other factors.

Accurate data in regard to the cost of pumping were very rarely obtainable, as at most stations tests had not been made, and costs of operation were not kept. Where steam pumps were used, the cost of steam and the amounts of water pumped were rarely known. Likewise with the air-lift, neither the amounts of water pumped nor the cost of running the compressor were accurately known. At most places where information in regard to pumping costs was obtained, the pumps or air compressors were motor driven, and thus the calculations were based on the amount of electricity consumed, however, there were variations in the cost of the electricity. Further, when the cost of pumping is given, it does not include depreciation and other fixed charges that generally exist.

Deep-well and centrifugal pumps.—The costs of operation of the small steam pumps were not obtained, but these are noted for their inefficiency. In most places where they are used, large quantities of water are not needed, so that it may not always be advisable to install more efficient equipment at an increased expense.

Many of the smaller towns that have motor-driven deep-well pumps have turned the management of the pumps over to large electric companies. The electric company then charges the towns a given amount per thousand gallons for delivering the water into the city mains. The rate is in most cases 4 to 5 cents per thousand gallons. Generally the municipalities own the wells, pumps and other equipment, although the electric company looks after the repairs, except for new parts. Commonly a representative of the company attends to the pump, although most pumps require little attention as they have automatic starting and stopping devices. The towns of De Kalb, Morris, Barrington, Lemont, and others have found this arrangement satisfactory.

At one city where the electric company owns the water works, it is able to pump water for one cent per thousand gallons. However, this includes no depreciation, and the lift is not over 50 feet.

The No. 7 well at Rockford, which is equipped with an "American" 17-inch, 6-stage combination deep-well and pressure pump, has a high efficiency as indicated by the tests made by the city engineers. Further

description of the Rockford equipment will be found under the discussion of that locality. The following is a reported test of this pump.

Capacity—1,380 gallons per minute.
Discharge pressure—61½ pounds equal to 142 feet.
Static head to center of pressure gauge—95.57 feet.
Total head of 237.57 feet.
Theoretical Horse Power would be 82.1.
Meter reading ahead of transformers—116 K. W.
90% Efficiency Transformers—104.4 K. W.
90% Efficiency Motor—93.39 K. W. or 125 H. P. delivered to shaft of pump.
Efficiency of pump—65.5%.

The output of this pump for 12 hours per day was 960,000 gallons at 65 pounds pressure. The electricity consumed was 1,400 K. W. at 1¼ cents per K. W. H. or a cost of 1.82 cents per 1000 gallons. The estimated cost, including depreciation and other fixed charges, is 2 cents per 1,000 gallons.

A reported test on an electrically driven, turbine deep-well pump in Chicago gave a cost of 1.8 cents per 1,000 gallons. The pump delivered 500 gallons per minute against a head of 216 feet; the electricity was calculated at one cent per kilowatt hour. No depreciation nor fixed charges were included.

Another test on a deep-well pump in Chicago follows. This is a motor-driven, double-acting, deep-well pump rated at 600 gallons per minute. During the test 530 gallons per minute were pumped against a head of 175 feet. The cost was 1.06 cents per 1,000 gallons counting current at 1.2 cents per kilowatt hour. No costs other than the actual consumption of electricity were considered.

Air-lift pumps.—An idea of the widespread use of the air-lift system of pumping may be gained by noting that in Chicago 86.8 per cent of the water obtained from wells 1,000 or more feet in depth is pumped by the air-lift.

One of the largest packing concerns in the Stock Yards district whose wells are pumped by this method reports a cost of 3.22 cents per 1,000 gallons which charge includes repumping to the different departments after it has first been brought to the surface by means of the air-lift. This company pumps as much or more than any other firm in Chicago, and the pumping equipment is probably as efficient a representative of the air-lift as can be found in the city. On a test this firm was able to obtain as low as .72 cubic feet free air per gallon delivered. Ordinarily one gallon is equivalent to about .85 cubic feet free air. These results were obtained with about 60 per cent submergence, pumping against a head of approximately 230 feet.

These satisfactory results were obtained without the use of a foot piece on the air pipe. However, the lower 8 or 10 feet of the air pipe was

perforated by a number of small holes whose total area was equivalent to about three times the area of the pipe cross-section.

The above pumping cost of 3.22 cents is approximately equaled by another Chicago packing company which reports slightly less than 3 cents per 1,000 gallons. This latter figure includes only pumping to the surface and does not consider depreciation nor fixed charges. The head pumped against is at least 230 feet.

The previously cited examples of efficient air-lifts are owned by concerns which have a number of wells and pump a very large amount of water. Companies pumping only 200 or 300 gallons per minute and with less modern equipment, undoubtedly have higher pumping costs.

The cost of air-lift pumping varies in the plants owned and managed by the municipalities. This is to be expected as the height to which the water must be raised is not everywhere the same; likewise some equipments are more efficient than others. The tendency in many instances is to make the cost of pumping appear as low as possible, so that many items that should be included are omitted. In general the pumping costs range from 3 to 7 cents per 1,000 gallons, no depreciation nor other fixed charges included. Most of these data can not be considered very satisfactory, as all of the necessary information could not be obtained.

YIELD AS RELATED TO DIAMETER OF WELL

Most of the wells drilled in northeastern Illinois up to five or ten years ago were completed with a diameter at the bottom of five inches or less. In wells of this size, where the water-bearing formation is 1,000 or more feet below the surface, the friction of the water against the walls is great. Where pipe is used instead of leaving the well uncased, the friction is somewhat reduced. If the diameter of the well is increased, the pipe or wall friction is greatly reduced, and more water is obtained at a less draw-down.

This may be illustrated by considering typical 8-inch deep wells in Chicago. These wells are about 1,650 feet in depth, and the important water-bearing sandstone is encountered at 1,350 to 1,400 feet. A well of the above depth and a bottom diameter of eight inches, with the water level at 200 feet below the surface will yield twice as much as a well with the same amount of lowering and similar depth but finished at six inches. This increase is dependent not so much upon the increased size of the opening that penetrates the water-bearing formation, as upon the reduction of the wall friction, which the larger hole makes possible.

The wells of 10 and 12 inches also have an advantage over the 8-inch well, although the increase is not proportionate. The increase in yield

of the 12-inch well over the 10-inch is only about a third of that of the 10-inch over the 8-inch. In wells of this depth the advantage gained by wells over 12 inches in diameter is very slight as the important factor is then ground friction or the resistance to flow into the well. This ground friction is usually considered as proportionate to the yield or flow. In case the openings into the well become clogged, as by the filling of the interstices between the sand grains with foreign material, the ground friction may become very high. Cleaning the well or blasting the previous bed with dynamite or nitroglycerine will generally remedy these conditions.

PART II

BOONE COUNTY

Physiography

Boone County is situated along the northern border of the State, just east of the center; McHenry County adjoins it on the east, De Kalb County on the south, and Winnebago County bounds it on the west. The total area is but 293 square miles.

The part of the county south of Kishwaukee River has a rolling prairie topography without great relief. This type of topography continues northward along the eastern part of the county, but toward the north the altitude is greater, more hills are present, and the land as a whole is more rolling. The gravel plains which extend westward from the morainic belts in McHenry County are the controlling factors in determining the topography. The western and northwestern parts of the county are somewhat lower than the remainder and, if anything, more hilly. Some timber is found along the stream courses.

The principal drainage is effected by the Kishwaukee River and its tributaries which flow westward across the southern part of the county. The Kishwaukee joins Rock River in the county to the west. Rock River tributaries flowing westward drain the northwestern set of townships.

Geology

The greater part of the area is covered with glacial deposits although these are not so heavy as in McHenry County to the east. The gravel plains in the eastern part are related to the morainic systems of Wisconsin age which are present in the county to the east. The sheet of drift covering the remainder of the county is referred by Leverett[1] to the Iowan stage of glaciation.

The drift in the northern part of the county is generally at least 75 feet in thickness and in places is probably more. In the southern townships the drift is much thinner, so that in a few places the rock is

[1]Leverett, F., The Illinois glacial lobe; U. S. Geol. Survey. Monograph 38, p. 573, 1899.

within a few feet of the surface. There are some quarries in the two southern townships.

The rock formation underlying the greater part of the county is the Galena-Platteville limestone. This formation passes under the Maquoketa shale toward the southeast, so that this latter formation underlies the drift in this part of the county.

The only data obtained in regard to the deeper strata in the county are from a single deep well at Belvidere.

The record represents the formations that will be encountered in drilling in other parts of the county except for the overlying Maquoketa shale which is present in the southeastern part. The depths to the various strata will vary somewhat because of differences in surface elevations. The altitudes are greater in the northern townships, but the rise of the formations toward the northeast probably compensates for the higher elevation so that the depths to the various strata are somewhat similar to those at Belvidere. It would seem that the formations lie at their greatest depths in the southeastern corner of the county.

The St. Peter sandstone was struck in the Belvidere well at a depth of 340 feet and was 185 feet thick. The sandstone should therefore be a source of water in other parts of the county where a moderate supply is desired without drilling to any great depth. Below a depth of 725 feet a series of sandstones are present which continue to the bottom of the well.

Underground Waters

GENERAL STATEMENT

The county has a number of possibilities for developing underground water supplies. In case it should not be possible to secure sufficient supplies from wells 200 or 300 feet in depth, the St. Peter sandstone is present at a not much greater depth. Then finally there is the great series of "Potsdam" sandstones which lie about 200 to 300 feet below the St. Peter.

BELVIDERE

The city water supply is furnished by three deep wells which range in depth from 1,803 to 1,900 feet. The succession of strata is indicated by the record of well No. 3, which was drilled in 1909.

The first well was drilled in 1891 to a depth of 1,950 feet. This well flowed at first but ceased at the end of about a year. The second well was drilled in 1901 to a depth of 1,861 feet and at that time the level was 3 feet below the surface. The third well was completed in 1909, at which time the static head was 8 feet below the surface; no further recession has been noted. The effect of pumping is not exactly

known, but each well is capable of supplying 400 gallons per minute with a suction lift. The No. 3 well is 10 inches in diameter at the surface and cased to bed rock, or to a depth of 50 feet; the bottom diameter is 8 inches or somewhat less. The other wells have 8-inch surface and 6-inch bottom diameters; the amount of casing is probably similar to that in No. 3.

The temperature of the water from the 1,803-foot well was only 52.6° F., which is at least 7° F. lower than that of other waters from this depth. This temperature of 52.6° F. is that generally obtained from shallow well waters. It is therefore very probable that this well obtains large additions of water from horizons near the surface or at the utmost a few hundred feet in depth. This seems even more highly probable when it is noted that the waterworks plant is located in the valley of the Kishwaukee River and therefore at a lower elevation than the surrounding area.

The chemical character of the water is indicated by an analysis made in 1899 from the water in the 1,900-foot well. The water is moderately mineralized and contains chiefly the carbonates of calcium and magnesium. It is used for boiler purposes, but some soft scale would form.

The Chicago and North Western Railway Company also has a well which is 1,231 feet in depth. The water level is 23 feet below the surface, but the ground elevation is probably 20 feet above that at the city waterworks. The well delivers about 150 gallons per minute continuously; the dimensions of the bore are not known.

The chemical character of the water is similar to that from the city wells, although not quite so hard. The water is used in the locomotive boilers.

Log of the Belvidere city well, SW. 1/4 sec. 25, T. 44 N., R. 3 E.

Elevation—755 feet

Drilled in 1909 by J. P. Miller Artesian Well Co., Chicago

Generalized section

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and recent		
Surface material, sand, gravel, etc.	46	46
Ordovician system		
Galena-Platteville limestone		
Dolomite or limestone, gray	294	340
St. Peter sandstone		
Sandstone, white, rounded quartz sand	185	525

Description of strata	Thickness *Feet*	Depth *Feet*
Prairie du Chien limestone		
Sandstone and limestone	15	530
Dolomite or limestone, cherty	10	540
Dolomite or limestone, grayish red	10	550
Dolomite or limestone, gray	10	560
Dolomite or limestone, grayish red	15	575
Sandstone	10	585
Dolomite or limestone, gray	60	645
Shale, red	80	725
Cambrian system		
"Potsdam" group		
Sandstone	45	770
Sandstone, a slight reddish color	5	775
Sandstone, white	10	785
Sandstone; some red shale	65	850
Shale, red	10	860
Shale, gray	10	870
Shale, red	10	880
Shale, gray or grayish green	45	925
Sandstone	125	1050
Shale, gray	20	1070
Shale, bright green	20	1090
Shale, gray	10	1100
Sandstone, gray	70	1170
Shale, gray	10	1180
Sandstone, gray, medium grained	20	1200
Sandstone, gray, fine grained	15	1215
Sandstone, gray, medium grained	5	1220
Sandstone, shaly, fine grained	5	1225
Sandstone, gray, medium grained	5	1230
Sandstone, shaly, gray	10	1240
Sandstone, gray, medium grained	25	1265
Sandstone, red, medium grained	5	1270
Shale, sandy, red	10	1280
Sandstone, red, rather coarse grained	5	1285
Sandstone, red, medium grained	5	1290
Shale, dark red	5	1295
Sandstone, light yellow, medium grained	10	1305
Sandstone, red, fine grained	10	1315
Sandstone, red, fine grained	5	1320
Sandstone, coarse grained	5	1325
Sandstone, red, medium grained	10	1335
Sandstone, light pink, medium grained	60	1395
Sandstone, pink, medium grained	5	1400
Shale, red	5	1405
Sandstone, light yellow to pink	20	1425
Shale, dark red	3	1428
Sandstone, red, medium grained	2	1430
Shale, dark red	5	1435

Description of strata	Thickness *Feet*	Depth *Feet*
Sandstone, red, medium grained	3	1438
Shale, dark red	2	1440
Sandstone, pink, medium grained	10	1450
Sandstone, light yellow, medium grained	10	1460
Sandstone, light pink, medium grained	50	1510
Shale, sandy, red	5	1515
Sandstone, red, fine grained	5	1520
Shale, sandy, pink	5	1525
Sandstone, pink, fine grained	5	1530
Shale, red	10	1540
Sandstone, reddish yellow, medium grained	10	1550
Sandstone, grayish red, medium grained	97	1647
Sandstone, gray, medium grained	8	1655
Shale, grayish pink	5	1660
Sandstone, yellowish red, medium grained	5	1665
Sandstone, pink, coarse grained	5	1670
Sandstone, light pink, rather coarse grained	5	1675
Sandstone, light yellow, medium to coarse grained	20	1695
Sandstone, pink, medium grained	15	1710
Sandstone, light pink, fairly coarse grained	20	1730
Sandstone, gray, medium grained	10	1740
Sandstone, yellowish pink, coarse	15	1755
Sandstone, pink, medium to coarse	48	1803

COOK COUNTY

Physiography

Cook County, with Lake Michigan as the greater part of its eastern boundary is one of the largest counties in the State, having an area over 900 square miles. The maximum north and south extent is fifty miles, and the average width is about eighteen, although the western boundary is very irregular. The relief varies from the flat plain of Chicago and environs to the undulating surface of the western part of the county. There is a gradual rise from the level of Lake Michigan at 581 feet to the western part of the Chicago plain which has an elevation of 640 feet above sea level or 60 feet above the lake. This flat area is in the form of a crescent, with the lake forming the inner border. The northern tip is at Winnetka on the lake shore about eight miles north of the Chicago city limits. The outer border of the crescent then extends south and westward in the vicinity of Melrose Park and LaGrange; whence it swings eastward, passing through the village of Glenwood, and finally extending into Indiana at Dyer.

The transition from the Chicago plain to the region of undulating topography to the west is in some places noticeable, but in most cases the change is scarcely perceptible. This belt of undulating country, continuing southward from Lake County through the northwestern part

of Cook County, and extending across DuPage and the western, southwestern, and extreme southern part of Cook County, is called the Valparaiso morainic system. Many parts of this higher area have elevations of 200 feet above Lake Michigan, and in the extreme northwestern part of the county some points are 300 feet above the lake. This morainic system has an important bearing on the underground waters of this district, as will be shown later.

Drainage is not well developed, but it is accomplished chiefly by the Desplaines and Chicago rivers and their tributaries. The extreme northwestern part of the county is in the drainage basin of the Fox River. The southeastern part of the county, in the vicinity of South Chicago and Lake Calumet, is poorly drained by the Calumet River. This interesting stream has its source in the western part of La Porte County, Indiana, and for a distance of 45 miles flows sluggishly westward, paralleling Lake Michigan at a distance of only a few miles. At the city of Blue Island it abruptly changes its course and flows eastward for 20 miles, not over two or three miles north of its westerly course. The outlet to Lake Michigan is finally effected at two places. The peculiar course of this stream is due to the recession of the old Lake Chicago, the waters of which formerly flowed southward into the Desplaines River at Summit and through the Sag outlet.[1]

Geology

The greater part of the county is covered by a mantle of glacial drift consisting of clay, sand, gravel, and boulders; although in many places on the Chicago plain the drift is comparatively thin, and there are even a few outcrops, the bed rock is for the most part concealed by a heavy mantel of drift which has a thickness of 140 feet at Superior and North State streets, a location about three-quarters of a mile northeast of the junction of the North and South Branches of Chicago River. As there is very little surface relief, these variations in the thickness of the drift indicate that the underlying rock surface has prominences and depressions. The average thickness of the drift on the Chicago plain is about 60 or 75 feet. The drift is usually thick along the Valparaiso morainic system, thicknesses of 200 feet not being unusual; likewise in the northwestern part of the county in the vicinity of Palatine and Barrington and in Schaumberg Township the drift is 250 to 300 feet thick.

The Niagaran limestone is the underlying rock formation of Cook County and is the youngest of the indurated strata to have been preserved. Evidences, however, have been found of the existence at one

[1] Leverett, F., The Illinois Glacial Lobe: U. S. Geol. Survey Monograph 38, p. 420, 1899.

time in this region of deposits of a younger age than the Niagaran. At Elmhurst, in Du Page County, just over the western boundary of Cook County, Devonian fossils have been found in the crevices of the Niagaran limestone.[1] Also samples from a deep well drilled for the Grasselli Chemical Company, East Chicago, Indiana, which is 4 miles east of the Illinois-Indiana boundary at West Hammond, indicate 110 feet of shale and argillaceous limestone above the typical Niagaran, containing spores of plants called *Sporangites,* which have usually been considered indicative of Devonian age. The Niagaran limestone can be seen in many quarries along the Desplaines River as at Willow Springs. This formation has an interesting exposure in the southern part of Chicago, called Stony Island. The Niagaran is a rather compact, gray, subcrystalline limestone containing in many places so much magnesium that it is called a dolomite. The exposed surfaces in quarries weather to a light buff or gray color. In a few exposures the rock contains some bitumen and asphalt, occurring in pores and cavities of the limestone, and the presence of a noticeable amount of hydrogen sulphide in much of the water from the Niagaran limestone may be traceable to this cause. The thickness of this formation varies from less than 100 feet in the northwestern part of the county to over 450 feet in parts of Chicago.

The Maquoketa shale underlies the Niagaran limestone. The character of this formation in this locality can be inferred only from a study of the well drillings, which indicate a very compact, close-textured, gray or bluish-gray shale. The well records show a variation in thickness from 120 feet in the south part of Chicago to 250 feet in the Stock Yards, not over seven miles distant. The average thickness is probably less than 200 feet. The compactness of the Maquoketa shale prevents it from being a water-bearing formation. Indeed, it serves as an impervious stratum separating the waters of the Niagaran limestone from those of the Galena-Platteville.

The Galena-Platteville limestone, which underlies the Maquoketa shale, is a light gray to cream-colored gray, dolomite or limestone, in places cherty, containing considerable magnesium carbonate. The thickness ranges from 300 to 450 feet.

The St. Peter sandstone is the next formation in descending order. This was one of the earliest sources of considerable artesian water. The extreme development of the underground water resources in this county, particularly in Chicago and vicinity, has depleted the supply to a great extent. The St. Peter is composed of a remarkably pure, rather well-rounded, siliceous sand, ranging in size from a powder to grains one

[1] Weller, Stuart, A peculiar Devonian deposit in northeastern Illinois: Jour. Geology, vol. 8, p. 483, 1899.

millimeter in diameter but averaging less than .5 millimeter. The thickness varies abruptly; differences of 100 feet, between places a comparatively short distance apart, are not unusual. Thicknesses ranging from 20 to over 300 feet have been noted. The St. Peter sand was deposited on a very uneven surface of the Prairie du Chien limestone, which accounts for its great variation in thickness. The contact between the St. Peter and the underlying Prairie du Chien limestone is distinguished in many well drillings by a red shale and cherty horizon.

The Prairie du Chien limestone is in most places a dolomite gray in color, or gray with a faint brown tinge. In many places the lower part of the formation contains a dolomitic sandstone which has a notable content of disseminated glauconite or green sand. This is underlain by a sandy dolomite which is also somewhat glauconiferous. The thickness of this glauconiferous, sandy, and dolomitic zone is variable but about 50 feet is probably the average. This is underlain by the first heavy sandstone of the "Potsdam" group. It is difficult to say whether this sandy glauconiferous bed corresponds with Chamberlin's[1] Madison and Mendota of Wisconsin, or whether the underlying 200 feet of sandstone is the equivalent of the Madison. This sandy bed at the base of the "Lower Magnesian" is recognized only in a study of the well drillings and is not differentiated in the drillers' logs. It has therefore been thought best in this report to define the "Potsdam" group as beginning with the first heavy sandstone below the St. Peter.

The known succession of the "Potsdam" group, as the term is here used, can be divided into three divisions, in descending order. The first, or upper, consists of a 200-foot sandstone very similar to the St. Peter, although the grains are probably not so well rounded. This is the great water-bearing stratum of Chicago and Cook County, and is usually spoken of by drillers as the "Potsdam sandstone." The second division is a thickness of 300 to 350 feet of siliceous and dolomitic shales, interbedded with thin beds of shaly dolomite and dolomitic sandstones. The third division, which has been penetrated for at least 350 feet, is a medium to coarse-grained sandstone. The sand grains of the upper 250 feet of the lowest division are fine to coarse in size and vary from colorless to light yellow. The lower 100 feet is a chocolate-colored or reddish-brown sandstone.

This three-fold division is similar to a like stratigraphic succession recognized in Minnesota and Iowa, in descending order, as the Jordan sandstone, the St. Lawrence formation, and the Dresbach sandstone and underlying Cambrian strata; these divisions in Iowa and Minnesota may correlate with those of Illinois.

[1] Chamberlin, T. C., Geology of Wisconsin, 1873-1879.

Underground Waters

SOURCES

The waters of the surface deposits are of importance in some localities. The controlling factors in determining the quantity of water available in these unconsolidated deposits are the character and thickness of the drift and the surface drainage. In some cases the sand and gravel of the drift may be present in more or less irregular beds which vary in composition, thickness, and extent.

The surface drainage along the Valparaiso morainic system is so poor that a large amount of water soaks into the ground. This surface water later finds beds of sand or gravel which act as transmitting mediums; where these pervious strata are sloping and are overlain by compact clay beds, artesian conditions are produced, and wells drilled at lower elevations than those of the general region may flow. In many instances, even though the wells do not overflow, there is enough static head and water available to make these wells important sources of supply.

The amount of water in the underlying bed rock is likewise dependent upon that collected by the overlying drift. The limestone is more or less fissured and in many places definite water channels have been formed. It has also been found that the bed-rock surface underlying the morainic system has a somewhat greater altitude than the rock surface underlying the bordering ground moraine. Therefore, with the moraine acting as a collecting area at a higher elevation, wells along its border often yield large supplies of water. Such conditions exist along the western and southern boundaries of the county, as illustrated by the wells at Chicago Heights and vicinity, the collecting region of higher elevation being to the south. Also the shallow wells at Elmhurst and Hinsdale, just over the line in Du Page County furnish a large amount of water.

Particularly in the extreme northwestern part of the county, because of the heavy drift mantle, large supplies are obtained from wells terminating either in the drift or in the underlying Niagaran limestone.

Most of the towns of the western part of the county obtain their municipal supply from wells penetrating the "Potsdam" group, but as these wells are uncased undoubtedly some additional water is obtained also from the Niagaran limestone.

Every rock formation underlying Cook County, with the exception of the Maquoketa shale, is capable of yielding some water. The strata, however, that contain the largest amounts of water of artesian character are the "Potsdam" group and the St. Peter sandstone. The forma-

tions rise gradually toward the north and west until they finally outcrop in south-central Wisconsin. The porous rocks here become saturated with water from rainfall. The water is then transmitted through these pervious formations by gravity or hydrostatic pressure. The upward escape of the water is prevented by overlying impervious strata; it is only when these water-charged beds are tapped by drilling in a region of lower elevation than the collecting area that the waters escape. The hydrostatic head may not be sufficient in all cases to yield flowing wells, but the conditions are nevertheless artesian.

The sandy, glauconiferous horizon of the Prairie du Chien limestone, about 100 feet above the "Potsdam" group, is also water bearing. Some of the drillers' logs mention crevices at this depth. This water may have been forced upward from the underlying "Potsdam" group by its own hydrostatic pressure.

The Galena-Platteville in some localities contains a little water. However, because it is the usual practice to leave this formation uncased, it is probable that more water is lost through crevices than is gained.

The Niagaran limestone in many places yields large supplies of water, particularly where the region is overlain by a heavy mantle of drift. Wells in the Niagaran limestone at the borders of heavy belts of drift or moraines furnish especially large amounts of water.

There has been a general lowering of the static head of the underground waters of this county, particularly in Chicago, since the first wells were drilled. The amount of lowering is in direct ratio to the amount of development. For instance, in the Stock Yards at Chicago, where wells of very large capacity have been drilled within the past few years, the head has been dropping at the rate of about nine feet per year. The recession in this part of Chicago has been approximately 240 feet since 1889. In other parts of Chicago and the county the lowering has not been so rapid.

CHEMICAL CHARACTER

There is considerable difference in the amount of dissolved mineral matter in the waters from different depths. Water from the same bed at different localities shows also a variation, although in a unit area of the size of Chicago the waters from the same stratum are very similar. As the prevalent practice is to case the wells only through the surface drift and any caving formation that may be encountered, the artesian waters from lower horizons are possibly diluted by the waters from the upper beds. A large number of analyses of waters from this county have been made, and factors determining the chemical character will be discussed in describing the water from the different localities.

The water obtained from the drift and the Niagaran limestone is, as a rule, softer than that from the lower artesian horizons. It is not possible in all places, however, to secure a sufficient supply from these shallow depths.

In general, the water obtained from the first sandstone of the "Potsdam" group has a high mineral content. The sulphates and bicarbonates of calcium and magnesium are present in large amounts, and the water is not adapted to boiler use without treatment. Some water containing a small amount of the calcium and magnesium salts is obtained from the shaly sandstones of the second division in the "Potsdam" group. The amount, however, is small, as indicated by tests made on the Chicago and North Western Railway wells at Proviso. These wells are eight inches in diameter at the bottom and did not yield over 100 gallons per minute with a lowering of 200 feet in the water level. The sandstones of the third division of the "Potsdam" series cannot be penetrated for a great distance before salt water is struck; this is particularly true in Chicago and the southeastern part of the county.

Chicago

GENERAL STATEMENT

Many industries in Chicago requiring large amounts of water have been fortunate in being able to secure this supply from underground sources. Until within the past ten years the static head has also been so high that pumping has not been difficult. The wells of Chicago may be divided into two groups: (1) shallow rock wells, less than 500 feet in depth, which obtain water from the Niagaran limestone; (2) deep rock wells which are over 1,000 feet in depth and obtain their main supply of water from the St. Peter sandstone, Prairie du Chien limestone, and "Potsdam" group.

SHALLOW ROCK WELLS

The shallow rock wells penetrate the Niagaran formation and range from 200 to 500 feet in depth and average 300 to 350 feet. They are usually drilled where only a comparatively small amount of water is required, as not over 20 gallons per minute. The diameter of the surface casing varies from 4 to 8 inches, 6 and 8 inches being the sizes most used. The wells are finished at 3½ to 6 inches in diameter at the bottom, 5 inches being a common size.

The yield from these wells is not great; 15 to 20 gallons per minute is about the average, although some wells were reported yielding 25 and 35 gallons, and one at the Crane plant produces 75 gallons per minute. This latter figure is very unusual, and it is evident that a limestone crevice

has been penetrated which contains much water. It is probable that more water could be obtained from these Niagaran limestone wells by increasing their diameter. However, no large amount of water is contained in this formation at Chicago, and the yield from these wells will never in any way compare with that from the deeper rock wells.

The water level in the shallow wells is not constant but varies greatly within short distances and is also dependent upon pumpage and the number of wells in the neighborhood. Deep-well steam pumps, either single or double acting, are in general use.

DEEP ROCK WELLS

HISTORICAL DISCUSSION

Probably the first deep rock well drilled in Chicago was sunk in 1864 at the corner of Chicago and Western avenues.[1] A strong flow of water was obtained at a depth of 711 feet, probably in the lower part of the Galena-Platteville limestone. The water rose to a height of 80 feet above the surface or about 111 feet above Lake Michigan. This well has since been abandoned. The water level has greatly lowered since that time so that at present the level in other wells drilled in the vicinity is 150 feet below the surface. This is a lowering of 230 feet, and the present static head is of water from a lower horizon than that penetrated by the well drilled in 1864.

Since the drilling of this first well a large number of others have been sunk. It is not possible to determine the total number of wells drilled in the city, as a large number of them have been abandoned. However, from an incomplete record of the abandoned wells that have been located and of the present 125 or more wells in active service, it is probable that since 1864 at least 300 or 350 wells 1,000 feet or more in depth have been drilled. It is hardly apparent that more wells have ever been in operation than at the present time, but as old wells became clogged and the casings corroded, new wells were sunk instead of repairing the old ones. The recent tendency is to replace a group of old wells of small bore by one large well. More water has been obtained by this method and at a lower cost of pumping. There is no doubt but that a greater amount of water is pumped at the present time than ever before.

WATER-BEARING STRATA

St. Peter sandstone.—The earlier deep wells in the city obtained water from the St. Peter sandstone which in 43 logs is found at an

[1] Schufeldt, Jr., George A., History of the Chicago artesian well, Chicago, 1865: Religio-Philosophical Publishing Association, Chicago, 1897.

average depth of 894 feet, with an average thickness of 115 feet. The shallowest depth recorded is in the Stock Yards district, where it is 860 feet, and its greatest depth is in the southeastern part of the city, where it was found to be 988 feet in the Columbia Malting Company well. It may be even deeper in the extreme southeastern corner of the city, as four miles east in Indiana and at practically the same elevation its depth is 1,115 feet.

As the number of wells increased in Chicago, less and less water was obtained from the St. Peter horizon, so that at the present time scarcely a well obtains its chief supply from this formation. A test was made of the amount of water that could be obtained from this sandstone in a well drilled in 1912 at the Western Electric Co. in the western part of the city in which the St. Peter was 145 feet thick and 860 feet deep. The tests indicated that the supply was less than 20 gallons per minute.

Prairie du Chien group.—When it was no longer possible to obtain a sufficient supply from the St. Peter, the wells were drilled to 1,200 or 1,300 feet where a sandy and fissured stratum containing considerable water is present in the Prairie du Chien. This sandy stratum will yet yield from a well 6 or 8 inches in bottom diameter, over 100 gallons per minute. However, as a 200-foot bed of sandstone is found at 1,400 feet, the usual practice is to drill through this formation and complete the well at about 1,600 feet.

It is not to be inferred that no wells deeper than the St. Peter sandstone were drilled while this formation yielded large amounts, because wells obtaining water from the "Potsdam" group have been drilled for at least 35 years. The purpose is only to show the gradual deepening of all wells.

"Potsdam" group.—The first sandstone of the "Potsdam" group, which has already been referred to as the source of the greatest amount of Chicago's deep well water, is found at an average depth of 1,400 feet. The 29 drillers' logs used in determining the average depth gave also an average thickness of 192 feet. The variation in depth and thickness is probably due in part to the difficulty the drillers have in accurately differentiating the lower sandy member of the Prairie du Chien limestone from the main sandstone. There is probably a variation of over 100 feet in the depth with apparently the shallowest depth of 1,385 feet at the Stock Yards. The maximum is in the southeastern part of the city, where it is at least 1,495 feet as shown by the log of the American Malting Company at Kensington. This variation must be due to the dip of the formation, as there is only a difference of a few feet in the surface elevations.

The next division of the "Potsdam" group from about 1,600 to 1,875 feet is for the most part a shale, in places slightly dolomitic and sandy. The formation, because of its impervious character, contains very little water. Although a number of the wells penetrate it for a considerable distance, no increased supply of water is thus obtained.

A number of the wells draw water from the third division of the "Potsdam", or the lower sandstone. This is struck in the Sears, Roebuck & Company well in the west-central part of the city at 1,868 feet, and in the Stock Yards well it is found at about 1,875 feet, according to the drillers' logs. The water from this lower sandstone contains a large amount of dissolved mineral matter, particularly sodium chloride or common salt.

SIZE OF WELLS AND CASING

The wells in Chicago encounter at least two horizons that are likely to cave, and these formations are therefore most commonly cased off. The placing of this casing reduces the size of the hole, so that to secure a well finished at a definite diameter it is necessary to have the hole at the surface much larger. For instance, a typical well that is drilled at present has a hole drilled large enough to admit a 12-inch surface pipe to bed rock. This distance will vary, but is about 75 feet; the hole is then drilled 12 inches in diameter until the Maquoketa shale is passed at about 550 feet. This shale, which is about 200 feet thick, is likely to cave and is therefore cased off with 10-inch pipe. The well is then continued at 10 inches, or slightly less, until the base of the St. Peter is reached at about 1,000 feet, where another caving formation, present at many places, must be cased off with 30 to 60 feet of 8-inch casing, and the well is drilled to completion 8 inches, or slightly less, in diameter. A number of wells of this size and about 1,650 feet in depth have been drilled in Chicago during the past two or three years. These wells have proved satisfactory and yield as high as 700 gallons per minute.

A few large wells have been drilled in the Stock Yards district within the past few years, which have been 20 and 22 inches in diameter at the surface and finished at 15½ or 16 inches. The yield from these large wells has been enormous, one well testing nearly 2,000 gallons per minute for several hours.

PUMPAGE

Daily Supply.—During the summer of 1914, the number of wells in Chicago over 1,000 feet deep in active service was 125. The pumpage from these wells was over 30,100,000 gallons per 24 hours. Within a circle of a half-mile radius in the Stock Yards 26 wells delivered 13,450,-200 gallons, or 44.3 per cent of the total daily pumpage from the deep

wells in the city. Five wells in the Stock Yards area pumped 7,315,200 gallons daily or 54.4 per cent of the pumpage from the wells in the previously mentioned circular area. The pumpage from these five wells is also 24.3 per cent of the total pumpage from the 125 wells in Chicago. (See figure 1.)

It was also found that within the past 5 years a number of wells yielding a large amount have been drilled. The wells in active service were divided into two groups according to their age. It was found that 84 had been drilled previous to January 1, 1909, and that 41 had been drilled since that date up to the summer of 1914. The old 84 wells pumped only 13,900,000 or 46.2 per cent of the daily amount, whereas the 41 recently drilled wells pumped the remaining 53.8 per cent (fig. 2). This also corresponds with the great lowering of the static head within the past few years as shown by figure 3.

The 30,100,000 gallons of water pumped daily from the deep wells of Chicago is equivalent to a per capita consumption of 100 gallons in a city with a population of 300,000. This amount of water would also cover 100 acres to a depth of one foot.

Effects of heavy pumpage.—It is obvious that the more water obtained from a well or a group of wells, the greater the effect will be upon neighboring wells. Also, the greater the pumpage, the greater is the circle of influence.

The effect of the concentrated pumping in the Stock Yards district undoubtedly exerts an influence over a large area. The contour map of the artesian water table in Chicago (Plate IV) shows this depression at the Stock Yards, and the gradual rise in the static head as the distance from this locality increases. It is difficult, however, to note accurately the pumping effects of any one well or group of wells on others, as each of the many wells in the vicinity affect all the others.

The lowering of the water level in any single well during pumping depends upon such factors as: size of well, rate of pumping, presence or absence of casing, and number of neighboring wells. The size of the well plays a greater part in the lowering of level during operation than has commonly been considered in Chicago. This is due to the fact that the main water-bearing horizon lies at a depth of at least 1,400 feet, and the water therefore encounters considerable friction against the walls of the well in rising through this height. Another resistance to flow is the ground friction or the resistance to entrance into the well.

Pumping methods.—The greater amount of the artesian water is pumped by means of the air-lift. The pumping equipment of 97 wells or 77.6 per cent of the total 125 wells is the air lift, and these wells pump 26,130,740 gallons or 86.8 per cent of the daily pumpage. The great head

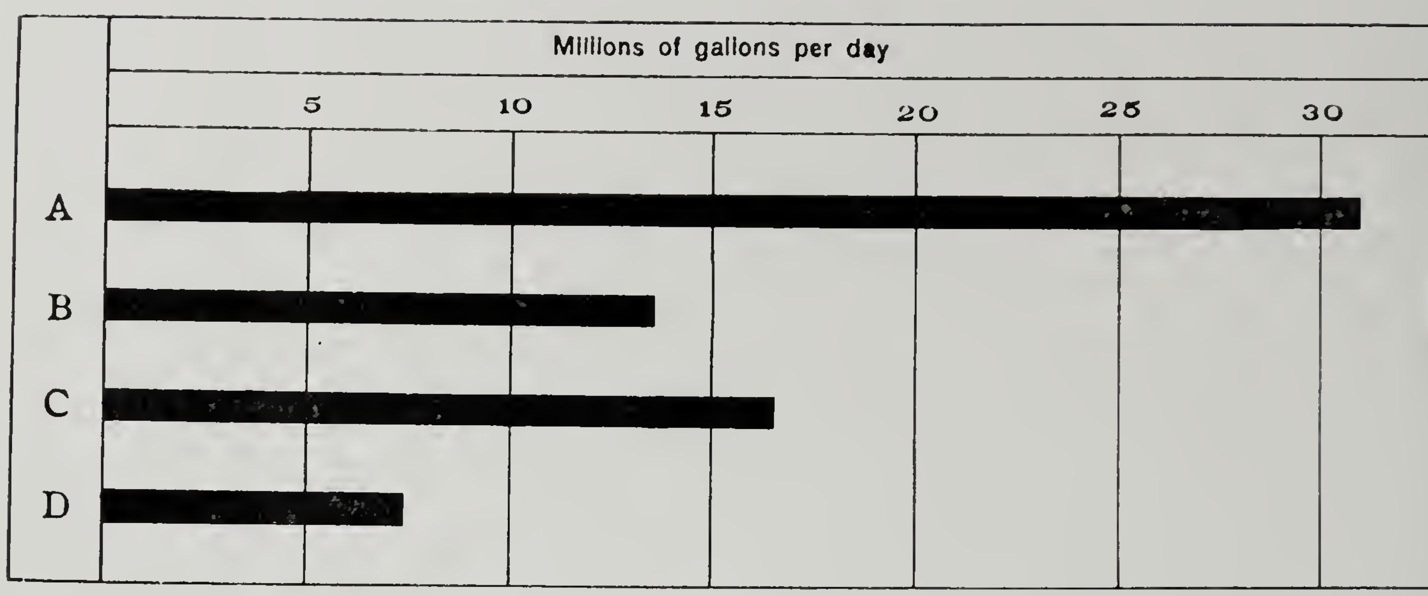


FIG. 1. Diagram showing the amount of water pumped daily in 1914 from:

A. All the deep wells in Chicago;
B. The 26 wells in the Stock Yards;
C. The 99 wells in the rest of Chicago;
D. The 5 largest wells in the Stock Yards.

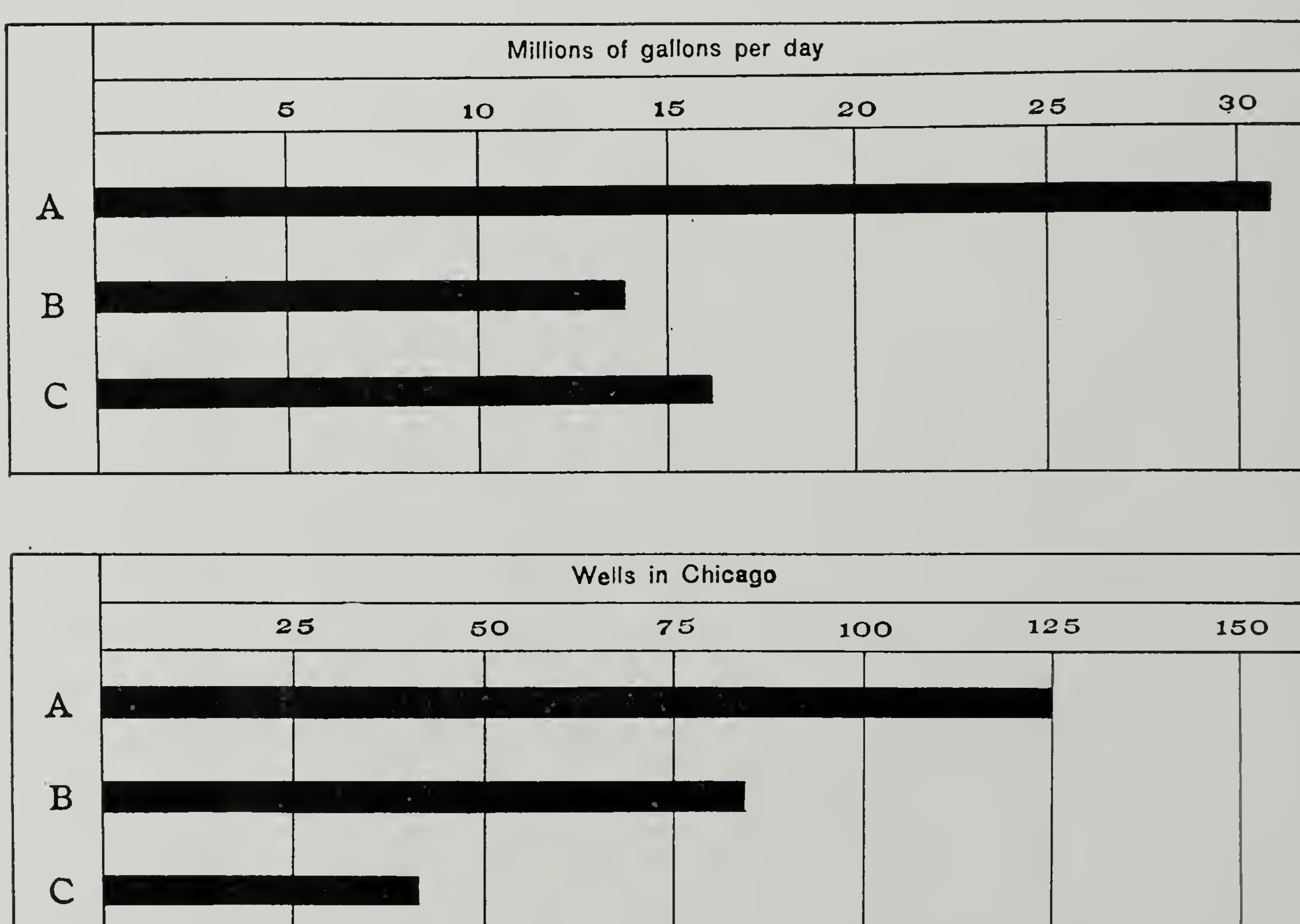


FIG. 2. Diagram showing the amount of water pumped daily and the number of wells in 1914 in Chicago for:

A. The entire city;
B. The wells drilled prior to 1909;
C. The wells drilled from 1909 to 1914.

to be pumped against (usually 200 or more feet), the flexibility gained, and the few repairs required by the air-lift system are probably the factors that have caused this method to be so widely used. Some of the wells are equipped with double-acting deep-well pumps and two or three multiple-stage turbine pumps are also in use.

Accurate pumping costs were difficult to obtain, so very rarely have they been determined. The largest consumers in the Stock Yards district, who have a number of wells pumped at high pressure, appear to obtain the water at the lowest cost. Some data regarding pumping costs are to be found in the chapter entitled "Wells".

STATIC HEAD

A large number of measurements of the water level in deep wells were made during the summer of 1914 by the writer and his assistant, Mr. Weiland. Other measurements have been made since that time to note accurately the lowering that has taken place. The methods of determining water level have been outlined in Part I under the discussion of "Static Head."

Galena-Platteville formation.—When the first deep well in Chicago was drilled in 1864, the water rose to a height of 80 feet above the surface or to an elevation of 695 feet above sea level. This well was 711 feet deep and probably obtained water from the lower part of the Galena-Platteville limestone. The static head has receded since that time until it is now many feet below the surface.

St. Peter sandstone.—The water from the St. Peter sandstone has been practically exhausted in the city and it was therefore not possible to determine its exact head. The well drillers report neither a dropping off nor a rise of the ground-water level in the well, when passing through this sandstone. This generalization regarding the St. Peter does not hold for the Stock Yards district. In drilling a recent well in this area, the surface water was carefully cased off to a depth of 500 feet and very little water was encountered until the St. Peter sandstone was reached. The water then rose to the general level of the "Potsdam" water in the Stock Yards district. This is apparently not the natural static head of the water from the St. Peter sandstone, because, as previously mentioned, in drilling deep wells in other parts of the city very little difference is noted between the ground-water level and that of the St. Peter water. The surface ground-water holds the water level during drilling at about 50 feet, until a depth of from 1,200 to 1,400 feet is reached, when the level drops to a depth varying between 150 and 235 feet, depending upon the part of the city in which the well is located. These latter figures indicate the head of the "Potsdam" water.

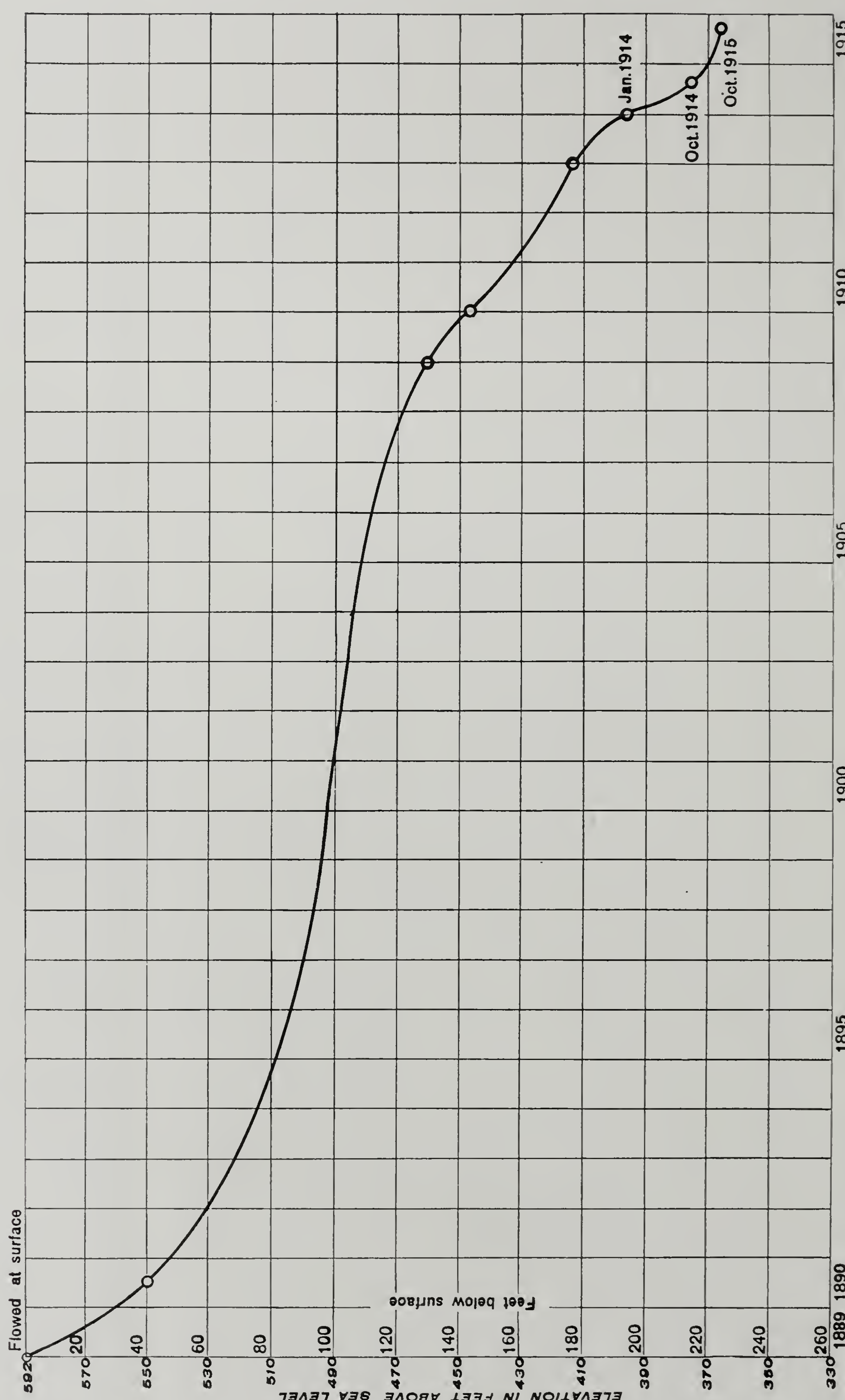
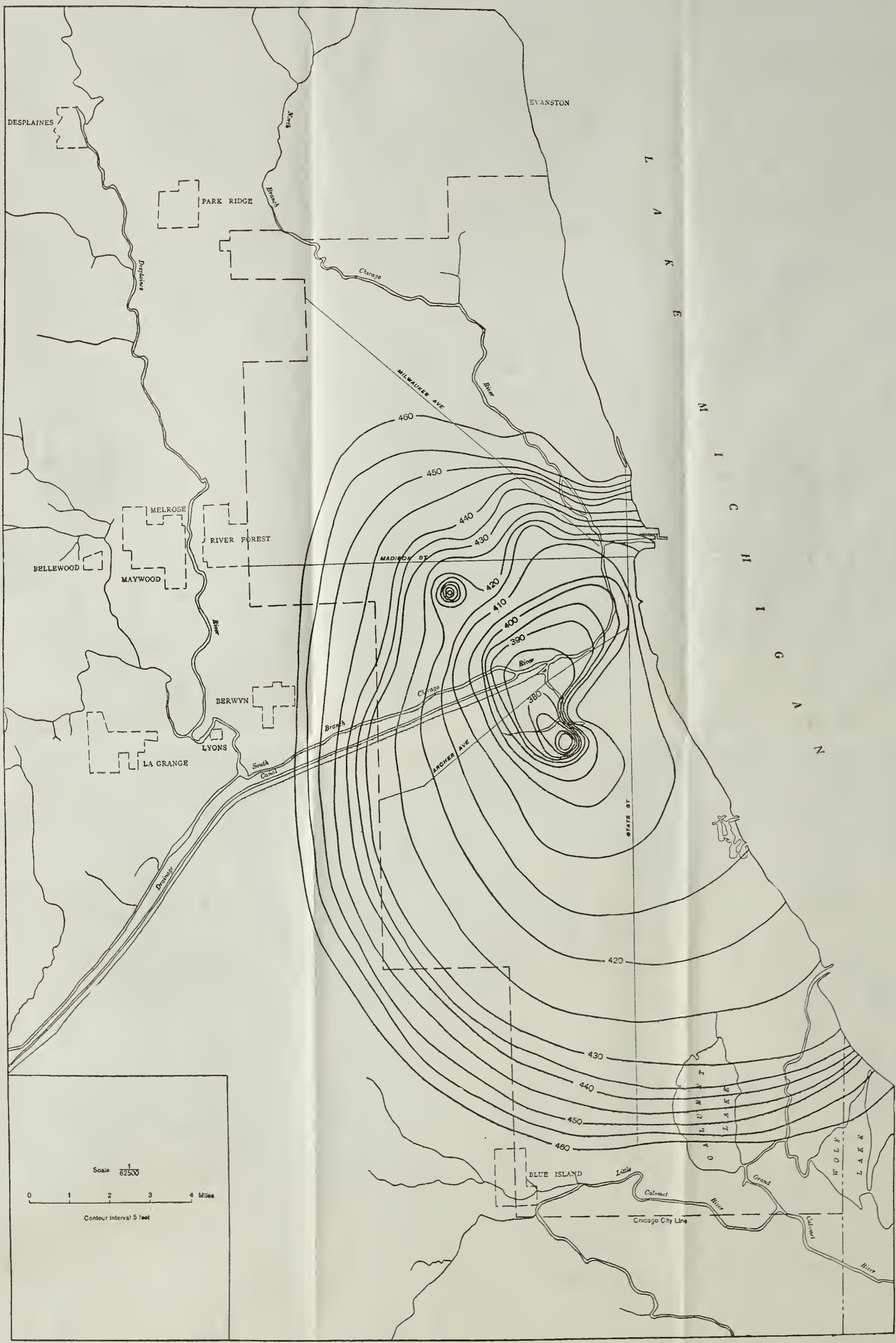


FIG. 3. Graph showing the lowering of the static head in the Stock Yards wells since they flowed in 1889.



Map of the Chicago district showing the Potsdam ground water level by means of contours

The St. Peter sandstone at one time contained considerable water, but tests made within the past few years indicate that in Chicago this source of supply has been practically exhausted. The amount obtained from this stratum in a test made by the Western Electric Company was less than 20 gallons per minute. The water level in the well, after passing through the St. Peter sandstone, was 68 feet below the surface or essentially the same as that of the ground-water table which had been nearly constant since drilling had commenced. Therefore, it appears that in the recently drilled well in the Stock Yards, the head of the St. Peter water which was practically the same as that from the "Potsdam" group, does not represent the actual head of the water originally contained in the St. Peter sandstone. It is, on the other hand, probable that some water from the "Potsdam" group rises and enters the St. Peter sandstone because of lack of casing in neighboring wells. This is very likely to be the case in the Stock Yards district where so many wells have been drilled within such a small area.

"Potsdam" group.—The present static head of the artesian water of Chicago is that from the first sandstone of the "Potsdam" group struck at about 1,400 feet. This is the water table that is contoured on Plate IV. The water table shows areas of elevation and depression. The area of greatest depression is in the Stock Yards, where in the summer of 1914 the pumping level was about 232 feet below the surface and 212 or 214 feet at rest. These latter figures showing the highest head for the district were obtained on a Sunday when some of the largest wells were idle. This measurement of 212 feet below the surface was probably the highest head in the Stock Yards during the summer of 1914. A few measurements in October, 1915, showed a level of about 240 feet during pumping and 225 feet at rest.

The highest head noted in the vicinity of Chicago was at Park Ridge, northwest of the city. The static head during the summer of 1914 was here 95 feet below the surface or at an elevation of 565 feet above sea level. This level was approximately 190 feet higher than that for the Stock Yards, about 15 miles to the southeast. In the south part of Chicago, at Riverdale, the head is about 90 feet higher than that at the Stock Yards about 12 miles to the northwest.

Data that showed the lowering of the water level in any one well over an extended period of years were not obtainable. The water level, however, is so uniform in the Stock Yards district that the measurements from a number of wells have been used to construct a curve (figure 3) showing the lowering of the static head since they flowed in 1889. The greatest lowering is seen to have taken place since 1907, no doubt to be accounted for by the considerable number of wells of large capacity drilled in following years.

CHEMICAL CHARACTER OF CHICAGO WATERS

NIAGARAN FORMATION

The shallow rock wells are cased only to bed rock, so as to shut off the surface sand and gravel; therefore this casing generally extends less than 100 feet below the surface. The water is found in the crevices of the limestone, into which it has seeped down slowly as surface water from the overlying drift. Generally a long period of time has elapsed since the water left the surface before it is pumped from the wells. It may have percolated through beds of sand and gravel or flowed through the limestone crevices. The water during this period has been in contact with more or less soluble rocks, and it therefore contains some dissolved mineral matter. Most of these dissolved solids are bicarbonates of calcium and magnesium, the soluble forms of limestone, but other salts, such as the sulphated magnesium and the chloride, sulphate and carbonate of sodium are also present in small amounts. Samples of water from the typical shallow wells of Chicago were analyzed by the State Water Survey. The average analysis calculated from 31 samples is shown in Table 7.

TABLE 7.—*Average analysis of waters from 31 shallow wells in Chicago*

(Hypothetical combinations)

Compound	Parts per million	Grains per U. S. gallon
Sodium nitrate ($NaNO_3$)	1.82	.11
Sodium chloride (NaCl)	39.77	2.32
Sodium sulphate (Na_2SO_4)	20.92	1.22
Sodium carbonate (Na_2CO_3)	97.10	5.66
Magnesium carbonate ($MgCO_3$)	39.57	2.31
Calcium carbonate ($CaCO_3$)	38.58	2.25
Iron carbonate ($FeCO_3$)	2.84	.16
Undetermined	17.63	1.03
Total	258.23	15.06

It is believed that the calculated analysis of the 31 analyses represents the average water obtained from the Niagaran limestone in Chicago. This water, although it contains nearly twice the amount of dissolved mineral matter found in Lake Michigan water, is nevertheless considered a soft water. The amount of scale-forming solids is small. The water is used for boiler purposes in a number of factories and scarcely any trouble has been reported; the scale is comparatively soft and easily removed.

Altogether 36 samples of shallow-well waters were collected, but as 5 of these waters are somewhat different from the others, they are not

included in the average analysis. These 5 waters contained some magnesium sulphate which was not found in the other 31 analyses. This magnesium sulphate was a negligible amount, less than a grain per gallon, except in two cases. The two shallow wells that contained a considerable amount of this scale-forming magnesium salt belong to Hoerbers Brewery and to Miller and Hart. In both cases the exact depth of the well was not known, and there is a possibility that they are deeper than the indicated approximate depths. If such is the case, it explains why the water is harder than that from the usual shallow well, as the water from the lower horizons contains more magnesium sulphate.

GALENA-PLATTEVILLE FORMATION

It is difficult to say anything definite concerning the water from the Galena-Platteville limestone, as few wells end in this formation. The wells either do not reach the base of the Niagaran limestone or else they continue to 1,200 feet or more. The water is present in crevices and doubtless the quantity is less than that in the Niagaran. As the formations are both limestones, the characters of the water are probably similar although that from the Niagaran is likely to contain a greater amount of hydrogen sulphide.

ST. PETER SANDSTONE

Very little can be said concerning the mineral character of the St. Peter sandstone water. Only one or two wells in Chicago end in this formation and these well waters show practically no difference from that obtained from the Niagaran limestone, except for a slight increase in mineral content. The wells are of small bore, have only surface-pipe casing, and are equipped with low-capacity pumping equipment so that the greater part of the water may be from the Niagaran limestone. The only well in Chicago thought to end in the St. Peter sandstone and pumping an appreciable amount of water was the one located at the Gutman Tanneries. This well is supposed to be 990 feet in depth, but as it is very old there is some doubt concerning this measurement. The water obtained is very similar to that obtained from wells 1,400 or more feet in depth. As there are a number of wells of this depth in the immediate vicinity, there is a possibility of water from these wells entering the Gutman well either by crevices in the limestone or through the St. Peter sandstone. None of the wells has casing other than the surface pipe and that for caving formations.

It was thought that water could be obtained from the different strata while a well was being drilled by collecting water from the bottom of the bailer. This was done at the American Malting Company and the

analyses are given in the appendix. The results were not a success as the analyses indicate Niagaran limestone or surface water in all cases. The well was cased with surface pipe only so that Niagaran limestone water must have been continually running into the well. Further, the bailer was open at the top, which evidently permitted upper strata water to enter. In order to obtain an accurate sample of the water from any horizon, the casing should be carried completely down to the water-bearing formation. Even with this precaution, it is best to have the well pumped for some time before the sample is collected. If more than one water-bearing stratum is penetrated, and a sample from a particular one is desired it is of course necessary to case off the others.

PRAIRIE DU CHIEN GROUP

The next water horizon of any importance below the St. Peter sandstone is in the basal part of the "Lower Magnesian" or Prairie du Chien limestone group. This horizon, struck at from 1,200 to 1,300 feet, is characterized by a distinctly sandy and somewhat shaly phase. Grains of glauconite are present and in some cases give a green color to the drillings. Distinct water channels, which may be only sandstone beds, are present; this horizon is called "the Crevices" by the well drillers because a large part of the well drillings tend to flow away, suggesting the existence of some openings.

The water obtained from the wells which stop at about this horizon is not essentially different from that in wells 1,600 to 1,700 feet in depth. These deeper wells draw their main supply from the first sandstone of the "Potsdam" group which lies immediately below the sandy, glauconiferous stratum of the base of the "Lower Magnesian" limestone. This first sandstone of the "Potsdam" group, which is about 200 feet in thickness, is the chief water-bearing formation underlying Chicago and the surrounding territory. It is very probable that the escape of water upward from this horizon into the overlying sandy and glauconiferous stratum accounts for the presence and similarity of the water.

"POTSDAM" GROUP

Upper Sandstone Member.—The character of the water from the "Potsdam" sandstone is shown by over 125 appended analyses. Most of the analyses have been made by the rapid method of boiler-water analysis used in the laboratory of the State Water Survey, although a few of the more complete mineral analyses of representative waters have also been made. The determinations made are given in all cases as well as the calculated hypothetical combinations of ions.

In order to determine the average composition of the water from the first sandstone of the "Potsdam" group, the average analysis was

calculated of the waters from 57 wells pumping over 75 gallons per minute and ranging in depth from 1,200 to 1,750 feet. The pumping restrictions were applied because it was found that wells which delivered less than 75 gallons per minute were influenced by waters from the uncased upper strata.

"POTSDAM" GROUP

TABLE 8.—*Mean analysis of the waters from 57 representative wells in Chicago pumping over 75 gallons per minute and ranging in depth from 1,200 to 1,750 feet.*

Dissolved solids	Parts per million	Grains per U. S. gallon
Sodium nitrate ($NaNO_3$)	2.09	.12
Sodium chloride ($NaCl$)	334.84	19.52
Sodium sulphate (Na_2SO_4)	265.72	15.49
Magnesium sulphate ($MgSO_4$)	184.26	10.74
Calcium sulphate ($CaSO_4$)	226.86	13.22
Calcium carbonate ($CaCO_3$)	212.30	12.55
Iron carbonate ($FeCO_3$)	1.14	.06
Undetermined	51.05	2.98
Total	1,278.26	74.68

A list is also added showing the number of wells of the different depths that comprise the above group of 57.

Number of wells of the different depths

Depth *Feet*	Number
1200—1300	5
1301—1400	5
1401—1500	4
1501—1600	15
1601—1700	25
1701—1750	3
Total	57

It is seen that 40 out of the 57, or 70.2 per cent, range in depth from 1,501 to 1,700 feet. This also represents the depth of the average deep well in Chicago. A number of these wells extend below the first "Potsdam" sandstone, in some cases for 150 feet, but the underlying formation is a shale for the most part and contains scarcely any water.

The average of the 57 analyses indicates that the water contains a considerable amount of mineral matter. It might be called a sulphate water, although considerable sodium chloride and calcium carbonate are also present. The detrimental constituents from the point of view of boiler usage are the sulphates of magnesium and calcium, present in large

amounts. These salts, in the quantities indicated, produce a hard, heavy scale when the water is used in boilers. The water could be softened, but it is not done in Chicago because of the accessibility of the soft lake water. There is a possibility that the water from the first "Potsdam" sandstone has a lower mineral content than that indicated by the average of the 57 analyses. This would be due to the lack of casing in the wells and the consequent addition of water from the Prairie du Chien limestone. However, in view of the fact that some wells in the Stock Yards which do not extend below the first sandstone of the "Potsdam" series deliver over 1,000 gallons per minute, it would seem that the greater amount of the water is from this sandstone.

The water has a pleasant taste and is used for drinking purposes in many manufacturing plants. The water is used in those industries which require a large amount of water and where the mineral content is not a factor. For example it is used extensively for cooling and washing purposes. The temperature of the water, about 59° F., and the absence of variation with the seasons, is in many cases an advantage. The iron content, although not high, is nevertheless in some instances sufficient to discolor wash basins and other porcelain ware. Some of the largest users of the deep well water are the packing houses, breweries, malting houses, vinegar manufacturers, steel mills, and cold storage companies.

Middle sandstone member.—The middle sandstone member of the "Potsdam" group is struck in Chicago at about 1,600 feet and is from 300 to 350 feet thick. This formation is composed of siliceous and dolomitic shales intercalated with beds of shaly dolomite and dolomitic sandstone, a few feet thick, and of such a character that it could not be a water-bearing formation of any importance. Data regarding the character of the water from this stratum were obtained in drilling the Sears, Roebuck & Company well in 1912. This well was originally drilled to a depth of 2,057 feet, but salt water was struck and the lower 189 feet was later filled in with concrete, leaving a depth of 1,868 feet.

Through the courtesy of Mr. Mory, chemical director of this company, analyses are here given of the waters from the lower depths. Samples were obtained by collecting the water from the boiler. The log of the well indicates a 26-foot bed of sandstone at 1,822 feet and tests showed that the water from that horizon contained very little, if any, permanent hardness. The analyses suggest a similar water to a depth of 1,960 feet. The waters below this horizon and to the final depth of 2,057 feet, show a rapid increase in the mineral content, particularly in sodium chloride, or common salt. The well was first drilled to a depth of 1,960 feet and cased with 1,788 feet of 8-inch discharge pipe. The bottom of the casing was sealed with 2 feet of concrete. The well as thus

equipped obtained water from 192 feet of strata, comprising the base of the shaly second division of the "Potsdam" group as well as some 90 feet of the upper sandstone of the third division. An analysis of the water from this horizon, made by the State Water Survey, is given. The total mineral content is 1,770.3 parts per million, by far the larger part of which is made up of the chloride and sulphate salts of sodium. It will be noticed that the scale-forming magnesium sulphate is present in a small amount, 57.6 parts per million, or 3.36 grains per gallon. There is, however, a considerable calcium carbonate content. The amount of water obtained with this piping arrangement was small, about 75 gallons per minute, and in order to increase the flow, the casing was cut off at a depth of 1,547 feet and 694 feet of pipe removed, leaving a length of 853 feet extending down from the surface. This discharge pipe was firmly sealed at the base with a rubber packer. The removal of this length of casing permitted the entrance of waters from the first sandstone of the "Potsdam" group and any other higher water-bearing horizons below 853 feet and the flow was increased to over 500 gallons per minute. The well was also filled in with concrete to a depth of 1,868 feet. The analysis of the water was obtained with this new pumping equipment is given. On comparison with the water delivered when the casing extended to 1,788 feet, it is seen that the water obtained with the shorter casing is much harder. There is a considerable increase in the sulphates of magnesium and calcium and no sodium sulphate, although it is possible that another analysis might show a small amount of this latter salt.

These data seem to indicate that a small amount of water can be obtained from the second division of the "Potsdam" group which is softer than that from the first "Potsdam" sandstone. The mineral content of this softer water is as great as that from the higher horizons, but the amount of hard scale-forming salts is less. The Sears, Roebuck & Company data show, however, that to obtain this water it is necessary to case to below the first "Potsdam" sandstone, which is at least 1,600 feet, and that only a small amount of water can be expected. In this instance the discharge pipe was 8 inches in diameter with a 6-inch hole below and only about 75 gallons per minute were obtained. The lowering in water level when this amount was being pumped is not known, but it was undoubtedly great. After the removal of the 694-foot length of pipe, over 500 gallons per minute were obtained with the same pumping equipment; the lowering in the water level while operating was probably 20 or 25 feet.

Lower sandstone member.—The lower division of the "Potsdam" group is a succession of sandstones the downward extension of which is not known, although they have been penetrated in this vicinity to a depth of at least 2,300 feet. They are generally struck in Chicago at a depth

of about 1,900 feet; in the Sears, Roebuck & Company well they are encountered at 1,868 feet. An increase in the salinity or total mineral content accompanies the increase in depth; this is shown in the analyses of the water from the lower strata in the Sears, Roebuck & Company well. A number of wells in the Stock Yards district, 2,000 or more feet in depth, deliver a water of high salinity, a high chlorine and sodium content being particularly characteristic. The greatest salinity of any well water in Chicago is possessed by that from the Oleomargarine House well of Morris & Company; the depth is approximately 2,300 feet. The mineral analysis of this water is given in the appendix. The salinity is 5,350 parts per million of which 2,900 are chlorine and 1,232 sodium. The hypothetical combinations show a very large amount of sodium chloride and the chlorides of calcium, magnesium, and potassium. The carbonate and sulphate salts of calcium are also conspicuous. The salt content of this water is so high that it has a brackish taste and is impossible for drinking purposes.

The water from the 2,164-foot well at the Independent Brewery is interesting because of the high content of sodium sulphate. The total mineral content is similar to that of the water from other wells of approximately this depth, but these wells usually have a much greater amount of chlorine.

Local Supplies

VICINITY OF CHICAGO

BLUE ISLAND

A few deep wells have been drilled in Blue Island, and the water obtained is essentially similar to that from wells of corresponding depths in Chicago. Analyses of water from representative deep wells are given.

The succession of strata does not vary noticeably from that in Chicago, so that the main water-bearing formation is penetrated at about 1,450 feet. This is the first sandstone of the "Potsdam" group, approximately 200 feet thick. Therefore the average well is about 1,650 feet in depth, although the gas plant of the Public Service Company of Northern Illinois has a well of 2,100± feet in depth. This well was drilled in 1912 and is reported to have overflowed when a depth of 1,940 feet was reached. There is no log of this well, but it is probable that at about this depth the lower sandstones of the "Potsdam" group were struck; the water from these lower strata has a somewhat greater head than that from the higher beds. However, the curb elevation of this well is from 40 to 50 feet lower than that of other wells in the vicinity, as, for instance, those at the Blue Island Water Works; this accounts in part for the apparently greater head. The present water

level in the gas plant well is not known, but there has been a considerable lowering since the well was drilled as a deep well pump has been in use for at least three years. The analysis of this water shows a higher mineral content than that of waters from shallower wells. The water has also a strong gaseous odor but as there is only a small amount of casing, this is probably due to the leakage from surface waters which have been affected by wastes from the gas house.

The municipal water supply of Blue Island had been obtained until August 1915, from 3 wells ranging in depth from 1,100± to 1,649 feet. At the above time arrangements were made to buy lake water from Chicago and the deep well pumpage was discontinued. The reasons for the change were the desire to obtain a softer water, the development of a gaseous odor in one of the wells, and the rapid lowering of the static head.

The gaseous odor in the well water, noticed in the early part of 1914, is probably related to the gas works about 1,000 feet to the southwest and at a lower elevation. It may be that because of lack of casing, surface water enters the deep well at the gas plant and finally by underground connections reaches the deep wells at the city water works. Other instances of a similar nature have been noted; at Joliet a new well situated near an abandoned gas plant developed an odor which could not be removed even by pumping to waste nearly a million gallons per day for a year. A 350-foot well in Chicago developed a very noticeable gas odor when a gas plant was built about 800 feet away. The well had been in use 14 years and no gas had been noted, but a year after the gas plant began operation the gaseous odor became very noticeable.

The oldest records regarding the water levels at the Blue Island wells are from 1910. In March of that year the static head of the water in the 1,649-foot well was 172 feet below the surface at rest or at an elevation of 469 feet above sea level; pumping at the rate of 380 gallons per minute for 24 hours lowered the water 33 feet. Measurements made on this well June 11, 1914, indicated a working level of 251.5 feet during pumping at the rate of about 300 gallons per minute; the other 2 wells were each pumping about 200 gallons per minute. The 3 wells are situated at the corners of a triangle, the sides of which are approximately 125 feet in length. After being shut down for 2.5 hours the water level in the one well rose 11 feet; the other wells were still in operation. In 1914 the water level was reported to be about 230 feet when all the wells were shut down: this would indicate a lowering of 58 feet in 4 years.

HARVEY

The city of Harvey, which is a little over 3 miles south and east of Blue Island, obtains its water from four deep wells. The average depth is 1,600 feet.

The succession of strata and their depths are similar to those in the south part of Chicago. The main water-bearing formation is penetrated at 1,400 to 1,450 feet and is approximately 200 feet in thickness.

The analyses in the appendix indicate that the water is hard and contains a rather high mineral content; it is similar to that from wells in Chicago and Blue Island of corresponding depths. The low mineral content of the No. 1 well water is very probably due to dilution by water from the Niagaran limestone, as the casing is in poor condition, and only a small amount of water is pumped. It is reported that the first well was drilled to a depth of 2,100 or 2,200 feet, but salt water was encountered, and the well was later plugged at about 1,600 feet. This indicates that a well of 1,600 to 1,650 feet gives the best results, as the shales and dolomites immediately underlying this depth contain practically no water, and the sandstone at around 1,900 and 2,000 feet yields a salt water or at least one of a high mineral content.

The static level at Harvey, in common with that of Chicago and nearby cities, has lowered considerably during the past few years. The figures below indicate the lowering in No. 4 well since 1911; the depth is 1,600± feet. Surface elevation is 600± feet.

Water levels in well No. 4, Harvey

Date	April, '11	Sept., '12	March, '13	March, '14	June, '14	June, '15
Feet below surface	105	116	120	130	135	155

The present water level is much higher than at Blue Island, although it is to be expected that the static head at Harvey should be 40± feet above the former because of difference in surface elevations. This, however, does not account for all of the difference; it may be that the lower level at Blue Island is due to heavy pumpage and proximity of other wells. The level at Harvey in 1915 was only 17± feet below that at Riverdale, 2½ miles to the north and east. This is a good comparison.

RIVERDALE

The village of Riverdale obtains a part of its municipal supply from a Niagaran-limestone well of 434 feet in depth. The water in 1910 was 15 feet from the surface, but had lowered to 46 feet in 1914. The yield is about 125 gallons per minute, but pumping at the rate of 140 gallons per minute for 12 hours lowers the level to 200 feet below the surface.

Evidently a fissure containing a good flow was struck in drilling this well, as other wells in this vicinity of the same depth yield very little water. However, wells of 1,650 feet in depth will produce a good supply. The static head of the first "Potsdam" sandstone water was 143 feet below the surface or at an elevation of 452± feet. This measurement was obtained in October, 1915, at the 1,720-foot well of the Pope Sugar Beet Factory.

SOUTHEASTERN COOK COUNTY

GENERAL STATEMENT

No good records have been obtained from southeastern Cook County south of Chicago city limits and east of Harvey. A set of drillings, however, has been studied from the 1,840-foot well of the Grasselli Chemical Company at East Chicago, approximately 4 miles east of the state line at Hammond. The first "Pottsdam" sandstone was penetrated here at a depth of 1,636 feet. This indicates that the strata have an eastward dip of about 18 feet per mile. Therefore in order to pass through the first "Potsdam" sandstone, the wells in this part of the county should be about 1,750 feet in depth. The static head in the Grasselli well was reported as 92 feet below the surface or an elevation of 495± feet; this is high when compared with those to the west. No analysis of the water was obtained, but it probably has a mineral content as high as, or even higher than that at Harvey.

The region south of a line through Palos, Homewood, and Glenwood has a greater relief and a heavier mantle of drift than the Chicago plain to the north. Therefore in prospecting for a water supply in localities underlain by the heavy deposit of sand and gravel, it should be determined whether a sufficient yield could be obtained from depths of a few hundred feet before drilling deeper.

Log of well owned by Graselli Chemical Co., East Chicago, Ind., in the SE. 1/4 sec. 33, T. 37 N., R. 9 W.

Elevation—587 feet

Drilled in 1915 by the Needham Well Co., Chicago.

Generalized section [a, b]

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Sand and gravel; no samples	40	40
Devonian system (and Mississippian?)		
Shale, calcareous	32	72
Shale, very dark gray	29	101
Shale, calcareous or argillaceous limestone	49	150
Silurian system		
Niagaran limestone		
Dolomite, gray to brownish gray	490	640
Ordovician system		
Maquoketa shale		
Shale, bluish gray	135	775
Galena-Platteville limestone		
Dolomite, light brown	341	1116
St. Peter sandstone		
Sandstone, colorless, fine to medium grained	64	1180
Prairie du Chien group ("Lower Magnesian" limestone)		
Chert and sand	11	1191
Dolomite, light gray to gray	314	1505
Sandstone, with glauconite grains	26	1531
Dolomite, sandy, glauconiferous	105	1636
Cambrian system		
"Potsdam" group		
Sandstone, colorless, fine to medium grained	201	1837
Dolomite, sandy, glauconiferous	3	1840

[a] The detailed log of this well compiled from study of samples is to be found in the Survey files if desired for reference.

[b] Mr. Ulrich has examined this log and has made the following comments: "Fail to see any grounds for referring all beds between depths 40-150 feet to the Devonian". He suggests that the sample of 101-150 feet may be Devonian, but that between 40-101 feet probably represents Kinderhook. Regarding the interval between 775-1116 feet he says of the "Galena-Trenton limestone", as this interval had been designated in the log sent him: "This term is a misnomer whatever this interval may represent. It is certain that most of the interval is of the age of the Black River stage. The typical Galena is younger and in my opinion of Trenton—probably early Trenton—age. At present, however, it is doubtful if any typical Galena occurs in eastern Wisconsin and northeastern Illinois. At least I have not observed Ordovician dolomites in east Wisconsin that are unquestionably younger than Black River. As a formation name the term Galena dolomite requires redefinition. It should be confined to beds above Chamberlin's 'Upper Blue' ". Regarding the interval between 1180-1505 feet which is designated "Lower Magnesian" limestone, Mr. Ulrich says: "For immediate purposes it is not improper to call these beds 'Lower Magnesian' limestone, but the term should be in quotation marks and followed by (Shakopee

and Oneota dolomites) in parenthesis, as here written. I object to Prairie du Chien, and shall recommend its abandonment." The interval between 1505 and 1531 feet seems to be the Madison sandstone, according to Mr. Ulrich, and 1531-1636 feet most probably represents the Mendota dolomite. "Glauconite is not common in these formations in Wisconsin. Though occasionally present, I doubt that it is either here or there an original deposit. Like much of the quartz sand, so also this glauconite was washed out of preceding Cambrian deposits and redeposited in the early Ozarkian formations." About the interval between 1636-1488 feet he is doubtful—"It may be basal Mendota."

The interval between 1648-1837 feet "is probably Jordan sandstone, with a good chance that the upper part includes reworked sands that were redeposited in the succeeding Ozarkian period". And finally the strata between 1837-1840 feet are "probably a dolomite of the kind often found in the upper part of the St. Lawrence."

CHICAGO HEIGHTS

The city supply of Chicago Heights is furnished by 4 wells 12 inches in diameter which penetrate the Niagaran limestone to a depth of about 300 feet. These wells yield 3,500,000 gallons per 24 hours, although 1,500 gallons per minute can be obtained from a single well. The appended analyses show that it is a hard water, although the mineral content is lower than that obtained from deep wells.

The static level in these wells has also dropped during the past 20 years, as seen from the table below; the surface elevation is 656 feet.

Water Levels at Chicago Heights.

Date		Feet below surface
	1894	4
June,	1908	39
November,	1908	43
January,	1909	50
September,	1909	52
July,	1914	60

This represents the gradual lowering of the surface water table and is entirely distinct from the recession of the artesian static head which is so noticeable in Chicago. The city of Chicago Heights is a manufacturing town and a large number of factories have their own wells. It is the combined pumpage in the city that has lowered the water table. The figures show that lowering has been more gradual in the past 5 years than in the previous 2 years, indicating that at the present pumpage only a slight lowering is to be expected in the future.

The collecting area of this water is the heavy belt of glacial drift to the south and west, the Valparaiso morainic system. This morainic area is at a higher elevation than Chicago Heights so that the rainfall which seeps into the drift and finally into the underlying fissured limestone, flows by hydrostatic pressure to the lower points. The village of South Chicago Heights has a deep well, the exact depth of which is

not known, although reported to be 2,500 feet. However, the mineral content, temperature, and static head indicate that the water is obained from the drift or Niagaran limestone. A well a few hundred feet in depth would yield the same quality and quantity of water.

MATTESON

Matteson has a 10-inch well which is 282 feet in depth. The water is obtained from the Niagaran limestone and is similar to that at Chicago Heights. The water level is 14 feet from the surface and recedes 8 feet in pumping at the rate of 200 gallons per minute. This level was maintained on a continuous test of 8 hours.

SOUTHWESTERN COOK COUNTY

GENERAL STATEMENT

The southwestern part of the county is covered by a heavy mantle of drift, which is part of the Valparaiso morainic system. This sand and gravel formation is a good collecting reservoir for the rainfall. It is therefore possible in many places to obtain a good supply of water from wells a few hundred feet in depth, which penetrate the Niagaran limestone. In case a supply is not obtained at the shallower depths, drilling could be continued to the St. Peter, or first "Potsdam" sandstone.

The St. Peter will probably be reached at from 850 to 1,000 feet, depending on surface elevation and dip of strata. This formation was found at 915 feet at Tinley Park and reported to be 146 feet in thickness; surface elevation is 690± feet. The St. Peter water level at Tinley Park was 10 feet below the surface in July, 1915. Wells which are intended to pass through the first sandstone of the "Potsdam" group would have to be from 1,500 to 1,700 feet in depth, because of variations in surface relief.

It is not possible to predict exactly the quality of the water obtainable from these lower strata, although there is every reason for believing it will be of good quality. The mineral content will probably be rather high so that it will not be usable in boilers unless treated.

Along the valley of the Desplaines River the depths to the water-bearing formations will be from 75 to 100 feet less than on the uplands bordering the stream. A number of springs occur along the base of the Desplaines River bluffs, as, for instance, at Willow Springs.

LEMONT

The municipal supply is obtained from a well 2,284 feet in depth. The mineral content is rather high, but the water is not hard as common salt is the principal mineral and the sulphates of calcium and mag-

nesium are absent. A 1,600-foot well would probably yield a water of lower salinity.

The water level was reported as 42 feet below the surface in 1912 and 53 feet in 1914. The surface elevation is 590± feet.

WESTERN COOK COUNTY

ARGO

The Corn Products Refining Company at Argo, about a mile south and a little west of Summit, has 7 deep wells in operation. The geological succession is indicated by the following log:

Log of well No. 8, Corn Products Refining Co., Argo, Ill., NE. 1/4 NE 1/4 sec. 23 T. 38 N., R. 12 E.

Elevation—590 feet

Drilled Aug.–Dec. 1914 by S. B. Geiger, Chicago

Generalized section[a]

Description strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent (samples missing)	38	38
Silurian system		
Niagaran limestone (samples missing)	310	348
Ordovician system		
Maquoketa shale (samples missing)	147	495
Galena-Platteville limestone		
Dolomite, gray, crystalline	305	800
St. Peter sandstone		
Sandstone, colorless, well rounded grains	260	1060
Shale, gray[b]	30	1090

[a] The detailed log of this well, compiled from study of samples, is to be found in the Survey files if needed for reference.

[b] Mr. Ulrich has the following to say in regard to the interval between 1060 and 1125 feet: "Finely laminated, hard, siliceous rock (would not like to call it shale) occurs in places in southeastern Wisconsin between the typical St. Peter and the Shakopee. Sometimes it includes, or is associated with, heavy chert conglomerate; and frequently there are red streaks or beds with the white. I regard these local deposits as erosion products, accumulated when the first Ordovician sea (the St. Peter) invaded this area. At one of these occurrences in Wisconsin I found these siliceous deposits transgressing the beveled edges of the Shakopee and finally resting on beds well down in the Oneota". As to the 90-foot interval between 1125 and 1215 feet, Mr. Ulrich is "inclined to regard this as Oneota and the Shakopee as absent". Of the strata between 1215 and 1255 feet, he says: "A few inches to 3 or 4 feet of green shale with chert is found at the base of the Oneota in many of the sections in Wisconsin. Commonly a large part of the chert is oolitic. Despite its much greater thickness (40 feet) in this well, I am strongly inclined to correlate this cherty shale with the otherwise similar deposit at the base of the Oneota in Wisconsin." The interval between 1255 and 1345 feet, and probably 1345 and 1355 feet is "evidently the Madison sandstone and Mendota dolomite". Between 1355 and 1535 feet, Mr. Ulrich considers the strata to be Jordan. Of the rocks between 1535 and 1795 feet and probably 1795 and 1825 feet, he says: "All of this suggests only the St. Lawrence. I doubt that the drill reached the Franconia".

Log of well No. 8—Concluded

Description strata	Thickness *Feet*	Depth *Feet*
Prairie du Chien group		
Chert, dolomite and siliceous oolite	7	1097
Shale, red and gray	28	1125
Dolomite, gray, crystalline	90	1215
Shale, greenish-gray	30	1245
Chert, white and gray	10	1255
Sandstone, contains glauconite	60	1315
Sandstone, dolomitic, contains glauconite	20	1335
Dolomite, sandy	10	1345
Cambrian system		
"Potsdam" group		
Sandstone, colorless, rounded quartz grains	205	1550
Shale, light gray to bluish green	50	1600
Shale, dark red or chocolate-colored	90	1690
Shale, green	55	1745
Dolomite	50	1795
Shale, bright green	15	1810
"Limestone" (samples missing)	15	1825
Sandstone	49	1874

The extraordinary thickness of the St. Peter sandstone at this place is noteworthy, especially on comparison with the record at Summit.

The combined yield of the 7 wells in July, 1915, was 1,250,000 gallons per 24 hours during continuous operation. The pumpage per well is not as great as for wells of similar size in Chicago and there is a possibility that some water escapes into the uncased St. Peter sandstone which is here over 250 feet in thickness. It may be mentioned that the yield of one of the wells was increased from 275 to 435 gallons per minute by shooting the water-bearing stratum with nitroglycerine.

The first well was drilled in 1907 but the original static head is not known. However, on evidence from the Clearing wells, it was probably about 100 feet below the surface. In July, 1914, the water level in No. 2 well was 212 feet below the surface while all other wells were in operation. The water levels in the other wells were approximately the same. The wells are from 450 to 1,200 feet apart.

A more complete test was made upon well No. 2 on July 5, 1915. The entire 7 wells were shut down at 5:45 a. m. and the first measurement obtained was at 7:13 a. m. The water level was then 223.5 feet below the ground surface. The ground elevation is 592 feet. Measurements were taken at frequent intervals during the following 9 hours. During the first two hours the total rise was 8 feet after which time the rate of recovery was much slower. At 4:33 p. m. the level was 191.5 feet below the surface and still rising at the rate of about a foot per

hour. This gave a total rise of 32 feet for the nine hours and twenty minutes, however, it is to be noted that the first measurement was not taken until 88 minutes after cessation of pumping. The test could not be continued longer as it was necessary to begin pumping.

This well was delivering about 600 gallons per minute; the other wells yield only 150 to 485 gallons per minute. No. 2 well is 1,507 feet in depth; the casing reported is 73 feet of 15-inch O. D. drive pipe to bed rock and 225 feet of 9⅝-inch casing for the Maquoketa shale; the well was finished at 8 inches.

A popular air lift system was in use at this plant until recently, but at the present time the following method is in use. Tests are made upon a well to determine its yield at the available air pressure. A discharge pipe is then used the diameter of which is slightly less than that required to deliver the water at the well's rated capacity. The purpose is to have the discharge pipe completely filled with water at all times. The only nozzle used is a perforated pipe about 5 or 6 feet in length which is screwed to the end of the air pipe. The holes are numerous, about ⅛ inch in diameter and drilled in at an angle.

The management states that better results are obtained with this new pumping arrangement.

The appended analyses of the waters indicate that they are fairly heavily mineralized as is customary from wells of these depths. The No. 7 water is somewhat softer, which may be either due to dilution from upper strata water or because a softer water is obtained from the greater depths; the former inference seems the more probable.

BELLEWOOD

The village of Bellewood in 1913 completed a 1,538-foot well which passes through the first sandstone of the "Potsdam" group. The well is 12 inches in diameter at the surface and finished at 8 inches. The yield was over 200 gallons per minute on a 100-hour pumping test. The water level was reported to be 75 feet below the surface in June, 1914; the surface elevation is 635± feet.

BERWYN

The municipal supply is obtained from a well approximately 1,600 feet in depth penetrating the first sandstone of the "Potsdam" group. The static head was reported as 113 feet below the surface in September, 1909, and 166 feet in June, 1914. The surface elevation is 605± feet.

CLEARING

The Chicago and Western Indiana Railroad Company has 3 deep wells at their Clearing yards in the SW.¼ sec. 21, T. 38 N., R. 13 E.

The wells are approximately 1,600 feet in depth and the geological succession is similar to that at Argo about 3 miles to the west. The St. Peter sandstone at Clearing has its usual thickness of approximately 125 feet; this is in contrast with the much greater thickness at Argo. The main water-bearing formation is the first sandstone of the "Potsdam" group.

These wells were drilled in 1901 and at that time the static head was 93 feet below the surface or at an elevation of 524 feet. In common with other wells in the Chicago area, the static head has been gradually lowering since that time. The recession in the water level since 1901 is given in Table I.

The water level in July, 1914, was 212 feet below the surface after the wells had been shut down for over 4 hours. Measurements showed that the water was still rising at the end of this period at the rate of 3 inches per hour.

The chemical analyses indicate that the water is fairly heavily mineralized. It is similar to that at Argo and Summit.

A new well, 16 inches in diameter at the surface and 8 inches at the bottom, was drilled in 1912. This well has not proved satisfactory as a yield of only 120 gallons per minute could be obtained with a submergence of 257 feet. The water level was reported at 145 feet. The well was also tested with 420 feet of air pipe with about the same yield as in the previously mentioned test. The water level would drop so low, however, that a large amount of air would be discharged.

This well is 1,605 feet in depth and penetrates the first "Potsdam" sandstone which in hundreds of other wells yields 200 and more gallons per minute. This well has only 36 feet surface drive pipe and 10-inch casing for the Maquoketa shale. It therefore seems very probable that crevices in the limestone have been struck in drilling which carry away a large amount of the water. There is also a possibility of the St. Peter sandstone causing some leakage. The remedy for this loss would be more casing.

FOREST PARK

The city owns two "Potsdam" wells which are 1,650± and 2,012 feet in depth. The 2,012-foot well is 14 inches in diameter at the surface and is finished at 8 inches; the other and older well is somewhat smaller. The deeper well is operated to a greater extent and delivers over 750 gallons per minute; both wells are pumped in summer and at other times of large consumption. The average daily pumpage for May, 1915, was 596,000 gallons per day. The 2,012-foot well is pumped by a six-stage turbine pump and the shallower well is equipped with an air-lift system.

The static level was reported as being 93 feet below the surface in November, 1901. The level February 4, 1914, was 163 feet below the surface after the 2,012-foot well had been shut down for 25 minutes; the wells are about 25 feet apart. On February 22, 1915, the level in the 2,012-foot well was 182.7 feet after the well had been closed down for several hours; however, the 1,650±-well was delivering 390 gallons per minute. The surface elevation is 625± feet.

The mineral analysis of the 2,012-foot well indicates a somewhat mineralized water, but the total content of dissolved solids is rather low for this depth. A little hydrogen sulphide gas was noted, particularly in the 1,650±-foot well; evidently some water is obtained from the fissured Niagaran limestone.

LA GRANGE

The municipal supply of La Grange is furnished by 3 deep wells operated by the Public Service Company of Northern Illinois. The wells are approximately 2,000 feet in depth and the water is obtained from the "Potsdam" and overlying strata. La Grange is at the western border of the Chicago plain and toward the west begins the Valparaiso morainic system. This morainic area is at a greater elevation, has more relief, and is covered by a heavier mantle of drift than the region to the east. There is therefore a strong probability that this elevated area acts as a collecting reservoir and that after the water reaches the underlying, fissured limestone it flows by hydrostatic pressure to lower points. This may explain the occasional occurrence of flowing shallow wells in the eastern part of La Grange.

It is also very probable that the deep wells receive considerable additions of water from the Niagaran limestone which is not cased off. This inference is strengthened when the analyses are compared with those from the shallow Niagaran limestone wells at Hinsdale, 3 miles to the west.

The La Grange wells range in size from 6 inches in diameter at the bottom to 16 inches at the surface. They are capable of yielding together at least 1,400 gallons per minute. The No. 3 well, which was drilled in 1910, delivered 1,020 gallons per minute on a 24-hour test. The temperature of the water from No. 2 was 56.5° F., which is low for a 2,000-foot well; this may be due to the cooling effect of upper-strata water.

There has been a lowering of the static level as in other deep wells of this territory, but the recession is not as marked. The following water levels were furnished by the operating company. Surface elevation is 635± feet.

Recession in artesian water level at La Grange

Date	Static feet below surface	Working feet below surface
1910	47	53
1911	53	60
1912	58	70
1913	65	80
1914	70	99

LYONS

The village water supply is obtained from a well 1,595 feet in depth, penetrating the first sandstone of the "Potsdam" group. The well was drilled in 1908, at which time the water level was 105 feet below the surface or at an elevation of 510 feet. The recession since that time is indicated below.

Recession in artesian water level at Lyons

Date	Feet below surface
July, 1908	105
December, 1912	128
July, 1914	137

This is a very moderate lowering as compared with that at Argo and Clearing. However, the well at Lyons is pumped at the rate of only about 50 gallons per minute.

The analysis given in the appendix represents a fairly highly mineralized water similar to that from other wells in the neighborhood of corresponding depths.

MAYWOOD

The water supply of the city is obtained from a 1,605-foot "Potsdam" well. The size is 16 inches in diameter at the surface and 8 inches at the bottom. There is also another well of similar depth but smaller bore which is equipped so that it is available in emergencies. The geological succession is indicated by the following driller's log:

Driller's record of well at Maywood

Elevation—630± feet Description of strata	Thickness *Feet*	Depth *Feet*
Soil, sand, clay	52	52
Limestone (Niagaran)	298	350
Shale (Maquoketa)	220	570
Limestone (Galena-Platteville)	270	840
Sandstone (St. Peter)	140	980
Limestone (Prairie du Chien)	420	1400
Sandstone ("Potsdam")	190	1590
Limestone ("Potsdam")	15	1605

The yield from the 1,605-foot well was reported as 700 gallons per minute for 23 hours per day. The water is fairly highly mineralized and similar to that at Melrose which is about 1.5 miles to the west. The temperature of the water was 57.7° F.

The following static levels were reported:

Water levels at Maywood; elevation, 630± feet

Date	Feet below surface
July, 1907	80
July, 1908	90
July, 1909	100
July, 1910	110
July, 1911	114
July, 1912	140
July, 1913	180.5
August, 1914	213[a]

[a] When pumping 700 gallons per min.

These levels seem very low when compared with those at Melrose. There is a probability that the wells had not entirely come to rest when the measurements were made. Also, the well is being pumped at a very high rate which would tend to lower the water level. The measurement of 1914 was made by the writer while the well was in operation.

The American Can Company, located a few hundred feet east of the Maywood city well, has two "Potsdam" wells. One of these was drilled in 1915 and the water level was reported at rest as 95 feet. This would indicate that the level in the city well has been greatly lowered by the heavy pumpage.

MELROSE

The municipal supply is furnished by two "Potsdam" wells, 1,620 and 1,571 feet in depth. The 1,620-foot or the older well, is 16 inches in diameter at the surface, and although it is only 4⅝ inches at the bottom, nevertheless the yield is 420 gallons per minute. However, the old well is only 50± feet south of the new large well, so that there undoubtedly is underground connection between them by means of the fissures in the limestone. The new well is 16 inches at the surface and 8 inches at the bottom and delivers 520 gallons per minute. These yields refer to the wells when they are operating separately, and it is probable that the delivery per well would not be as great when they are pumping together.

The water analyses indicate a somewhat mineralized water which is similar to that obtained from like depths in this locality.

The static head as reported is given below; the surface elevation is 630± feet.

Recession in artesian water level at Melrose

Date	Feet below surface	Remarks
October, 1912	75	About 85 when pumping
May, 1914	80	Lowers 9 feet in pumping; recovers in 3 hours

The water level in the 1,571-foot well was 97.5 feet below the surface when pumping at the rate of 520 gallons per minute; the other well was at rest. The well was shut down for an hour and a rise of 12 feet was noted with the water still rising at the rate of 1 foot per hour. The water levels in the 2 wells were found to be the same.

PROVISO TOWNSHIP

The Chicago and North Western Railway Company has drilled 8 wells at their Proviso yards which range in depth from 1,200 to 1,850 feet. The geological succession as determined by Prof. T. E. Savage from a study of the drillings is given below.

Log of well No. 3, Chicago and North Western Railway Co., SE. 1/4 NW. 1/4 sec. 5, T. 39 N., R. 12 E.

Elevation—643.6 feet

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and recent deposits		
Surface material, yellow clay and pebbles	5	5
Clay, gray; with pebbles	25	30
Drift till, pebbles	43	73
Silurian system		
Niagaran limestone		
Limestone, light gray, dense, fine-grained, subcrystalline	172	245
Ordovician system		
Maquoketa shale		
Shale, bluish gray	233	478
Galena-Platteville limestone		
Dolomite, light gray, fine grained	130	608
Dolomite, powdered, fine grained	77	685
Dolomite, fragmentary; small amount of rounded quartz sand grains	125	810
St. Peter sandstone		
Quartz sand, white, clean, well rounded	150	960
Prairie du Chien group		
Dolomite and limestone, fine grained. light gray; mixed with fragments of drab shale	70	1030
Dolomite, finely powdered; slight reaction with cold acid	150	1180

Log of well No. 3, C. & N. W. Ry. Co.—Concluded

Description of strata	Thickness *Feet*	Depth *Feet*
Dolomite, gray finely powdered, mixed with a considerable amount of rounded sand grains; slight reaction with cold acid	50	1230
Sandstone, brown to pink, fine grained. Larger fragments contain specks of a black mineral, probably glauconite	40	1270
Dolomite, gray; slight reaction with cold acid; some sand grains	60	1330
Cambrian system		
Potsdam group		
Sandstone; quartz, light brown; some finely powdered dolomite	100	1430
Sandstone, pure, cream colored, rounded grains	95	1525
Sandstone, brown; some finely powdered brown dolomite and gray chert fragments	15	1540
Dolomite, gray, subcrystalline, fragments coated with drab-colored shale	60	1600
Shale, calcareous, gray, sandy; considerable reaction with cold acid	165	1765
Sandstone, quartz, coarse, gray; grains considerably rounded	60	1825
Dolomite, light grayish brown, sandy	5	1830

These wells can be divided into two groups according to the chemical character of the water. The wells, 1,200 feet in depth, yield a somewhat mineralized water, as indicated by the appended analysis from well No. 2. The deeper wells deliver a less mineralized water that can be used in boilers without treatment. This difference in the mineral content of the waters from the different wells is not only due to differences in depth but chiefly in the deeper wells to the exclusion of the hard upper strata waters by casing.

The 1,200-foot wells have only the 70± surface drive pipe and 150± feet of casing for the Maquoketa shale. Therefore, the resulting yield from the well is a mixture of the waters from the Niagaran limestone, St. Peter sandstone, and the Prairie du Chien limestone. The deeper wells are 1,825 to 1,850 feet in depth and are completely cased from the surface to at least 1,522 feet. This length of casing prevents the access of all water above the base of the first "Potsdam" sandstone. The casings in the different wells are indicated in the table of analyses in the appendix.

The water from the lower "Potsdam" sandstone in these cased wells is of a low mineral content. However, this soft water is obtained at the sacrifice of quantity, as the 1,200-foot wells yield more water than those 1,800 feet in depth. The earlier deep wells were drilled in

the latter part of 1911 and in 1912; the size of the wells ranges from 12 to 15 inches in surface diameter and 6 to 8 inches at the bottom. A number of tests were made on the 1,800-foot cased wells but the maximum delivery was an average of 150 gallons per minute on a 2-hour test made on well No. 5, February 7, 1912. The water stood at 38 feet below the surface at the beginning of the test and the pump was at a depth of 165 feet. When the pump was speeded up so that the delivery was greater than 150 gallons, the pump drew air. This indicated a lowering of 127 feet in the water level under these pumping conditions.

Additional tests have been made by this company to determine the effects of pumping upon other wells in the vicinity. The wells No. 1, No. 3, and No. 5 are located along a straight east-west line; No. 5 is 600 feet east of No. 1 and No. 3 is half way between the two. The sizes and casings of the wells are as follows:

	No. 1	No. 3	No. 5
Size, inches	12–5	12–6⅝	12–8
Length of casing, feet	1550.5	1670	1723
Depth, feet	1825	1830	1841

The results of pumping tests in well No. 1 are given below, and also the lowering of the water levels in well No. 3. The pumping equipment of No. 1 was a 2-stage straight air-lift system.

Pumping tests on C. & N. W. Ry. wells at Proviso
(Beginning July 25, 1912.)

Time	Well No. 1 Water level Feet below surface	Well No. 1 Gallon per minute	Well No. 3 Water level Feet below surface	Well No. 5
8:50 a.m.	38	121	38	Stopped
10:00	216	114	....	Stopped
11:00	...	112	67.5	Pumping
12:00	226	112	....	Stopped
1:00 p.m.	226	112	81.5	Pumping
2:00	231	112	85.5	Pumping
3:00	233	112	89.5	Pumping
4:00	233	112	92	Pumping
5:00	233	112	93.5	Pumping
		(July 26, 1912)		
8:00 a.m.	38	115	38	At rest
8:20	214	...	....	At rest
9:00	221	110	....	At rest
10:00	226	110	65.5	At rest
11:00	226	110	68	At rest
12:00	228	110	71	At rest
1:00 p.m.	228	110	72	At rest
2:00	230	110	73	At rest
3:00	230	110	75.5	Started, 3:30 p.m.
4:00	230	110	79	Pumping

The test on the second day indicated that the water level lowered from 38 to 230 feet below the surface when pumping at the rate of 110 gallons per minute for 8 hours. It is notable that the water level receded to 214 feet after 20 minutes of pumping. The level in well No. 3, which is 300 feet to the east, lowered 37.5 feet during the 7.5 hours that No. 1 was being pumped.

Another test was made upon Nos. 1 and 5 on August 2, 1912, at which time the combined pumpage was approximately 225 gallons per minute. At the end of 9 hours' pumping the water level in No. 1. was 242 feet below the surface and 97 feet in No. 3. The level in No. 5 was not given.

The tests show that wells of this size yield about 110 gallons per minute with a lowering of 190 to 200 feet in the water level.

These results should be compared with those obtained from the 1,200-foot wells. These 1,200-foot wells are all of practically the same depth and cased with only 70± feet of 16-inch O. D. surface pipe and 160± feet of 10-inch casing for the Maquoketa shale; the bottom diameter is 8 inches.

An 8-hour test made September 10, 1912, on No. 2 averaged 150 gallons per minute. The water level was 73 feet below the surface at the start and 130 feet at the completion of the test. The pumping equipment was a deep-well pump with a 7.5-inch working barrel placed 160 feet below the surface.

The results of a test made upon well No. 4 are given below. The pumping equipment was a deep well pump with a 7.5-inch working barrel placed 200 feet below the surface.

Test on well No. 4, Aug. 9 and 10, 1912

Time	Water level Feet below surface	No. strokes per min.	Gal. per min.	Remarks
9:30 a.m.	83	36	156	August 9; started pumping
11:00	95	34	142	
1:00 p.m.	99	33	149	
3:00	103	40	183	
5:00	107	40	180	
7:00	107	40	172	
9:00	108	40	172	
11:00	109	40	183	
1:00 a.m.	109	40	172	August 10
3:00	109	41	183	
5:00	109	39	172	
7:00	110	40	172	
9:00	111	41	183	
11:00	111	41	183	Stopped pumping

A 33-hour test made upon well No. 7 with a deep well pump averaged 190 gallons per minute. The water level receded from 78 feet below the surface at the beginning of pumping to 113 feet at the end of the test; the level was 113 feet during the last 8 hours of pumping.

On comparing the results obtained from the uncased 1,200-foot and the cased 1,800-foot wells it is seen that the former yield 1.5 times as much water as the latter and with a less lowering of the water table. It is also noted that the water level in the shallower wells was originally about 40 feet lower than in the 1,800-foot wells, but that on pumping the recession was not nearly so great in the 1,200-foot wells as in the deeper ones. This all indicates that a larger supply of the hard water from shallow depths can be obtained than of softer water from the deeper horizons.

Temperatures of the water were obtained, but they show some variations. This is probably due to the slight heating effect of the air-lift system. The waters in the shallower wells, however, have a consistently lower temperature than those from the deeper horizons. The 1,200-foot wells are pumped with deep well pumps, whereas the deeper wells are equipped with air-lift systems. Nevertheless, the temperature differences can not be entirely explained on this basis, but are essentially due to the fact that the waters from the deeper strata are inherently warmer than those from the shallower depths.

Temperatures of wells at Proviso

Well No.	Depth *Feet*	Casing *Feet*	Temperature *Degrees F.*
1	1,825	1,551	60.4°
2	1,200	66	58.1°
4	1,203	76.5	52.8°
5	1,841	1,723	61.0°
7	1,202.5	70	51.5°
9	1,849	1,522	64.0°

RIVER FOREST

The municipal water supply is obtained from 2 wells approximately 1,000 feet in depth. There are no logs, but according to those of other wells in the immediate vicinity, it is evident that the St. Peter sandstone would be penetrated at this depth. Other factors are present, however, which seem to indicate that the water from the overlying strata contribute to a considerable extent to the water production of the wells.

The analyses in the appendix indicate a moderately mineralized water containing a small amount of scale-forming solids. Some hydrogen sulphide gas is noted as the water is pumped from the wells, but is not reported in the water drawn from the mains. The water is somewhat

similar to that from the Niagaran limestone because of this gas, but the mineral content as a whole is greater. The temperature was 52° F., which also is similar to that of the Niagaran limestone water. Then again when it is recalled that the well at the Western Electric Company, about 5 miles to the east, could obtain only 20 gallons per minute from the St. Peter sandstone, it seems very probable that the River Forest wells obtain considerable water from the Niagaran and the Galena-Platteville formations.

The wells are 10 and 12 inches in diameter at the surface and yield 110 and 150 gallons per minute, respectively. The bottom diameters are about 6 inches.

The water level in the larger well was 71 feet below the surface on August 15, 1914; the measurement was taken 53 minutes after pumping had ceased. A measurement made 5 minutes after cessation of pumping gave the level as 80.3 feet. The other well, which is at a distance of 150 feet, was in continuous operation. The surface elevation is approximately 625 feet.

RIVERSIDE

The municipal water supply is furnished by two "Potsdam" wells about 2,000 feet in depth. The wells were both completed in 1898 and the first one was drilled to a depth of about 2,200 feet. However, salt water was encountered and the well was later plugged at 2,000 feet. The other, or west well, was then drilled to a depth of 1,980 feet.

The wells are reported to have flowed when first drilled, but in 1899 the static head was 20 feet below the surface according to Leverett.[1] There was considerable fluctuation in the water level during the summer of 1914, but this was very probably due to unequal rates of pumping. The level in July of that year was 109 feet below the surface in the west well, after both wells had been at rest for six days. The pumping level in the same well was 169 feet below the surface when delivering water at the rate of 240 gallons per minute for twenty hours per day; the other well was not in operation.

During the month of July, 1913, there occurred apparently a sudden recession of the water table. The water level was measured in 1912 and found to be 70 feet below the surface in both wells. The static head in the east well was measured also in July, 1913, and found to be 70 feet below the surface. However, the level was again determined in the same well a week later and found to be 140 feet below the surface, or an apparent recession of 70 feet. No observation had been made in 1913 upon the west well until the lowering in the east well had been

[1] Leverett, Frank, The Illinois Glacial Lobe U. S. Geol. Survey Monograph 38, p. 589, 1899.

noted. The measurement was then made upon this well and found to be 110 feet as compared with 70 feet the previous year. The wells are not over 150 feet apart.

The writer's inquiries in neighboring towns to determine whether a similar recession had taken place at the same time revealed that only the normal recession had taken place. Although the recession in a number of wells at the Corn Products Refining Company at Argo, about 3 miles south of Riverside, has been very great since the first well was drilled in 1912, no unusual lowering was noted in 1913.

It therefore appears to the writer that the apparent sudden recession of 1913 may be explained by the differences in a level which exist between that of true "Potsdam" water and that of the general ground water table. It is known that in this region the ground water level is much nearer the surface than that of the artesian water from the deep-lying strata. In drilling deep wells, the water level is that of the ground water at about 50 to 75 feet below the surface, until the artesian water-bearing formation is penetrated when the water level suddenly drops and assumes the static head of the artesian stratum. Further, in many old deep wells, the water from the lower, artesian beds has been excluded by caving in of the upper parts of the well. The water level in such wells will be that of the general ground water table and not that of the deep-seated artesian strata. If wells of this type are cleaned, the water level is again that of artesian formations.

In 1913 it was known that there was a leak in the casing of the east well at a depth of about 57 feet and considerable water entered the well. Also in the west well, at about this same time, the level rose from 110 to 44 feet, although the water dropped rapidly in pumping and the amount obtained was not at all comparable with that produced by the other well. This indicates in every way, shallow, ground water.

Since that time both wells have been cleaned and recased. In the summer of 1914 the west or 1,980-foot well, had been completely cased to a depth of 302 feet and sealed off with a rubber packer. Therefore, the water level of 109 feet at rest very probably represents the static head at that time, as no ground water entered the well. The repairs upon the other well had not been completed at that time.

The high level of 70 feet in 1913 seems to have been that of the general ground water table; the lowering to 140 feet may have been due to the taking of the measurement before final recovery after a pumping test. This low level does not seem to be that of the true artesian water in view of the much higher level, i. e., 109 feet, in 1914. As the wells are only 150 feet apart and the same depth, the water levels should be the same unless modified by entrance of water from surface zones.

The appended boiler-water analysis given in the appendix for the water from the west well indicates its general characteristics. It is seen to be the typically rather hard water of the "Potsdam" wells.

SUMMIT

The village of Summit is situated on the Chicago plain and in an area where the underground waters have been heavily drawn upon. The city supply is from a 1,547-foot well penetrating the first sandstone of the "Potsdam" group. A new well was drilled in 1913, the driller's log of which is given below.

Log of well at Summit

Surface elevation—600 feet

(Authority, J. P. Miller Artesian Well Co., Chicago)

Description of strata	Thickness *Feet*	Depth *Feet*
Earth, sand and gravel	58	58
Limestone (Niagaran)	281	339
Shale (Maquoketa)	141	480
Limestone (Galena-Platteville)	324	804
Sandstone (St. Peter)	131	935
Limestone (Prairie du Chien)	405	1340
Sandstone	195	1535
Limestone	30	1565
Shale	80	1645
Marl, red; in streaks	65	1710
Shale	70	1780
Limestone	23	1803
Sandstone ("Potsdam")	54	1857

This new well, which is 17 inches in diameter at the top and finished at 8 inches, delivered 551 gallons per minute on a test. The pumping equipment was not installed in the summer of 1914.

The water from the old well is not highly mineralized when the depth of the well is considered. The other analysis which is appended is of the water which flowed into the new well at or near the contact of the surface casing with the bed rock. This leakage was at about 60 feet below the surface. These analyses on comparison are found to be very similar, although the water from the 1,547-foot well contains a larger amount of the sodium salts. It is therefore very probable that the water in the old well is diluted to a certain extent by leakage from the uncased Niagaran limestone.

The static head was reported as 95 feet below the surface in 1908; it had lowered to 142 feet in July, 1914.

WESTERN SPRINGS

The village of Western Springs in the latter part of 1913 completed a well approximately 1,600 feet deep. The water is from the "Potsdam" group and upper strata. The surface ground-water level was reported to be 14 feet below the curb, whereas the "Potsdam" water horizon was down to 134 feet. The surface elevation is about 665 feet.

NORTHERN COOK COUNTY

GENERAL STATEMENT

At the present time the suburbs along the North Shore all obtain their municipal water supplies from Lake Michigan, and any deep wells that were formerly in use have been abandoned. Wells in Evanston of 1,600 feet in depth were reported to have flowed up to 1900.

There is no doubt but that large supplies of water, comparable to those pumped from Chicago wells, could be obtained from wells in this part of the county at about 1,600 feet in depth. It is also very probable that because of the heavy drift mantle in the northern part of the county, considerable water could be obtained from the drift and Niagaran limestone.

DESPLAINES

The city water supply is furnished by 3 drift wells about 125 feet deep. The wells are located along the Desplaines River; one being within 8 feet of the stream, but the others are about 125 feet from the bank. The location of these wells along a stream course and at a low elevation with respect to the region, is conductive to obtaining water from shallow depths. An exceptionally good flow under sufficient pressure to rise within 15 feet of the surface, was encountered in a sand and gravel stratum at a depth of 110 feet. The drift is heavy in this region, averaging 100 feet and more, which forms a good collecting reservoir for the rainfall. It is therefore not unusual to obtain strong shallow wells in this locality; in fact, at the lower elevations, as along the Desplaines River north of Desplaines, flowing wells have in some places been obtained.

The wells at Desplaines are reported to be 6 inches in diameter and cased the entire depth; whether a strainer is placed at the bottom is not known. The yield is about 45 gallons per minute per well and the average daily consumption is 100,000 gallons.

A new well, 4 feet in diameter, was being drilled in July, 1915. The contract specified that a stratum of sand and gravel at about 110± feet should be penetrated. At a depth of 102 feet the drillers bored a small hole in the bottom of the well in order to determine how much farther

they must dig. Water was encountered which rose to within 15 feet of the surface and the contractors could not finish the well. It had not been decided at that time how the matter was to be settled.

The analysis of the water from the well nearest the river is given. The water has an unusually high mineral content for a drift well in this locality and would form a heavy scale when used for boiler purposes. The large amount of sodium chloride is unusual for a well of this type. The temperature of the water on August 17, 1914, was 10.7° C. or 51.3° F.

An 1,890-foot well has been drilled by the Chicago and North Western Railway Company at their Norma yards, about 1.5 miles west of Desplaines. The geological succession as determined from the driller's log and 17 samples taken at long intervals, is given below. The drillings were examined by Prof. T. E. Savage.

Record of C. & N. W. Ry. well at Norma

Elevation—655± feet

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and recent deposits		
Clay, soft	20	20
Gravel	15	35
Clay, soft	17	52
Gravel	13	65
Gravel and mud	10	75
Gravel	20	95
Gravel and clay	17	112
Gravel	23	135
Gravel and mud	35	170
Mud, soft	21	191
Mud, hard	2	193
Gravel	4	197
Silurian system		
Niagaran limestone		
Dolomite, gray, subcrystalline	106	303
Dolomite, gray to brown, subcrystalline	5	308
Ordovician system		
Maquoketa shale		
Shale, bluish-gray, calcareous	47	355
Galena-Platteville limestone		
Dolomite, gray, subcrystalline	35	390
Dolomite, gray	26	416
Dolomite, gray, subcrystalline	264	680
Dolomite, gray; a few clear quartz sand grains	20	700
St. Peter sandstone		
Sandstone, white to gray; rounded grains	30	730
Sandstone, like the preceding	10	740

Record of C. & N. W. Ry. well at Norma—Concluded

Description of strata	Thickness *Feet*	Depth *Feet*
Prairie du Chien limestone		
Dolomite, light gray, subcrystalline	230	970
Sandstone, fine, gray; mixed with redddish-brown dolomite	26	996
Dolomite, brown to gray; some fine-grained, sand	29	1025
Cambrian system		
"Potsdam" group		
Sandstone, gray; rounded quartz grains and a little gray dolomite	225	1250
Sandstone, gray; and dolomite, dark gray to light bluish	215	1465
Sandstone and dolomite, like the preceding	80	1545
Sandstone, light gray to brown; rounded grains	265	1810
Sandstone, like the preceding, but a little more reddish	80	1890

This well is 16 inches in diameter at the surface and finished at 8 inches. It is completely cased from the surface to a depth of 740 feet, or below the St. Peter sandstone. A pumping test was made on November 6 and 7, 1913, which averaged 200 gallons per minute over a period of 32 hours. The pumping equipment was a 7.5-inch deep-well pump placed at a depth of 107 feet. The water level before the test was 7 feet below the surface, but lowered quickly to 57 feet after the pump was started. It varied from this figure to 62 feet, depending upon the speed of the pump, which ranged from 25 to 29 strokes per minute.

The writer has not seen an analysis of the water, but the railroad chemist reports it fair for boiler use.

HUBBARD WOODS

The North Shore Distilled Water and Ice Company has a "Potsdam" well which is 1,437 feet in depth. The exact size of the well could not be ascertained, but it is probably 8 or 10 inches in diameter at the surface and 5 or 6 inches at the bottom. It is pumped continuously at the rate of 140± gallons per minute. The water level could not be measured.

The analysis which is appended indicates a water with a considerable mineral content. The Niagaran limestone probably contributes some water as the presence of hydrogen sulphide was noted.

PARK RIDGE

The village of Park Ridge has two "Potsdam" wells, 1,425 and 1,804 feet in depth, which furnish the local supply. The geological succession is indicated by the following driller's log. The formations are similar to those at Chicago, but they are at a less depth because of the dip to the southeast.

Driller's record of strata at Park Ridge

Elevation 660± feet

Description of strata	Thickness Feet	Depth Feet
Soil, clay, sand, and gravel	110	110
Limestone (Niagaran)	150	260
Shale, bluish gray (Maquoketa)	240	500
Limestone (Galena-Platteville)	320	820
Sandstone (St. Peter)	135	955
Limestone, slightly sandy (Prairie du Chien)	295	1250
Sandstone ("Potsdam")	175	1425
Shale, light greenish gray	300	1725
Sandstone	79	1804

The 1,804-foot well is 12 inches in diameter at the surface and completed at 6 or 8 inches; the other well has a surface diameter of 10 inches. The wells deliver from 175 to 200 gallons per minute each with the present deep-well epuipment.

The static head was reported to be 95 feet below the ground surface on August 4, 1914. Park Ridge is situated on the northern edge of the great static-head depression area in Chicago. The drop in the static head is very rapid from the village as the area of heavy pumpage to the southeast is approached. This decline is the more marked when notice is taken that Park Ridge is at an elevation of 70 feet higher than the Chicago Stock Yards district.

The analyses given in the appendix indicate that the waters contain considerable mineral matter and would form a moderate amount of scale if used in boilers untreated. The shallower well yields the harder water; the increase of the alkali salts in the water from the deeper well is noticeable.

NORTHWESTERN COOK COUNTY

GENERAL STATEMENT

The Valparaiso morainic system crosses the northwest part of the county and consequently the drift mantle is very heavy. Thicknesses of 200 feet are not uncommon and in the vicinity of Barrington, Palatine, and in Schaumberg Township, it has been found to be from 250 to 300 feet thick. The region has inadequate drainage so that the heavy sand and gravel mantle forms a natural collecting reservoir. Hence, good shallow wells are obtained which are in some instances under sufficient pressure to flow.

ARLINGTON HEIGHTS

The village of Arlington Heights is located in an area of slight relief east of the terminal moraine and at a lower elevation. The drift is from 128 to 150 feet in thickness.

The water supply is obtained from a 127-foot drift well 5 inches in diameter and a 10-inch well somewhat deeper. The larger well is reported to be cased to rock but the depth is not known; its yield is 180,000 gallons per day. The water level in both wells is 12 feet below the surface; ground elevation is 700± feet. No analyses have been made by the State Water Survey.

BARRINGTON

The village of Barrington is situated in the area of the Valparaiso morainic system and consequently the drift is very heavy; it was reported to be 200± feet in thickness in the well at the water works.

The municipal water plant is operated by the Public Service Company of Northern Illinois. The supply is obtained from a well 315 feet deep which penetrates the Niagaran limstone for about 115 feet. The surface diameter is 12 inches and the diameter is probably 8 inches at the bottom. The water level at rest is 20 feet below the surface and recedes about 5 feet when pumping at the rate of 400 gallons per minute. No variation in the water level between summer and winter has been noted. The average daily consumption in 1915 was 192,000 gallons.

The analysis of the water indicates a very moderate amount of total dissolved solids. The carbonates of calcium and magnesium predominate, but some sulphates are also present.

PALATINE

In the village of Palatine it is possible to secure considerable quantities of good water from wells of 150 to 175 feet in depth. The water is under sufficient hydrostratic pressure to produce flowing wells in some places. Thirty years ago the pressure was strong enough to raise the water 32± feet above the surface. There has been a gradual decline in the static head so that at the present time the water level is about even with the ground surface.

Flowing wells have been reported from other parts of Palatine Township, for instance, at the Kitson farm, about a mile west of Palatine, and at the Englking farm, located a little over a mile northwest of the village. At Staples Corner, Palatine Township, wells 172 feet in depth ending in gravel are reported to have a static head of 9 feet above the surface.

In Schaumberg Township, which adjoins Palatine Township on the south, flowing wells have been obtained from the drift or the upper part of the bed rock, especially along Salt Creek and its tributaries. The collecting area for this shallow well water is believed to be the Valparaiso morainic system, which lies to the west and north of Palatine.

Parts of this moraine have altitudes 100 to 120 feet above the station at Palatine.[1]

Mr. Charles Wente, a well driller at Palatine, reports that bed rock is struck in the village at 170 to 175 feet. The water in most cases comes from a bed of gravel overlying the limestone. The drilling is usually discontinued after the bed rock has been penetrated a few feet.

The village water supply is furnished by 3 wells which are each 168.5 feet in depth. It is not known whether rock was penetrated, but Leverett gives the depth as 152 feet in the town well. The diameters are 2, 6, and 10 inches; the casing extends to the bottom. The water level is about level with the ground surface when the wells are at rest. The 2-inch well is connected under ground with the reservoir so that it flows about 36,000 gallons per day when the other two wells are at rest. The level in the smallest well is 19 feet below the surface when the other two are pumping together 180± gallons per minute. The average daily consumption is about 100,000 gallons.

The water is moderately mineralized, containing for the most part the carbonate salts of calcium and magnesium, but no hydrogen sulphide gas.

DE KALB

Physiography

De Kalb County is in the second tier of counties south of the Wisconsin line and about midway between Lake Michigan and Mississippi River. The north and south length is approximately 36 miles and the width is 18 miles; the total area is 638 square miles.

The Bloomington morainic system enters the county in the northeastern part and crosses the area in a southwestward direction.[2] This belt has a width of 6 to 15 miles and is characterized by terminal-moraine topography, although the relief is slight. The elevations along this tract average 50 to 100 feet above the plain to the northwest and southeast. Knolls and basins with differences of relief from 10 to 40 feet are numerous. In the southwest part of the county the morainic belt has a tendency to separate into two, three, or four ridges. These ridges average a mile or less in width and rise about 30 to 50 feet above the intervening depressions. Outside this terminal-moraine area, the topography of the remainder of the county is gently undulating. Even the erosion along the stream courses has caused only slight relief.

The northern part of the county drains to the north through South Kishwaukee River and tributaries. The inner belt of the Bloomington

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[1] Leverett, Frank, The Illinois glacial lobe: U. S. Geol. Survey Mon. 38, p. 586, 1899.

[2] Leverett, Frank, Idem, p. 246, 1899.

morainic system enters the county from the east, just southeast of Sycamore, crosses the area in a southwestward direction in the form of slight curve, and passes into Lee County in the vicinity of Shabbona and Pawpaw. This slightly elevated strip forms a divide between the waters of the South Kishwaukee and the eastward-flowing tributaries of Fox River.

Geology

Almost the entire county is covered by a heavy mantle of drift. The average thickness in 22 borings was 151 feet, and in 68 other wells that did not reach rock, the average depth was 101 feet. The drift in the part of the county north of the outer terminal belt, which comprises T. 42 N., Rs. 3 and 4 E., and parts of adjoining townships, probably does not average over 50 feet thick. This would tend to reduce the average thickness for the remainder of the county. The greater part of the drift is composed of a blue till containing a few intercalated beds of sand and gravel.[1]

The boundaries of the different formations which form the bed rock are not definitely known in this county because of the heavy mantle of drift. The data that have been obtained are from well drillings, and these seem to indicate that the Galena-Platteville limestone is the bed rock formation underlying the greater part of the county. This was the first formation struck in the wells at De Kalb and at Sycamore. Likewise at Malta the bed rock given in the driller's log is 210 feet of limestone.

It is probable that the Maquoketa shale cuts across the northeastern corner of the county as a narrow strip a few miles wide. The strata dip toward the east and south, but because of the much lower altitudes in the southern tier of townships, it is possible that in some places the St. Peter sandstone is the bed rock. The drill record from Somonauk mentions "sandstone and limestone" as underlying the surface deposits. Near Earlville in La Salle County, less than 3 miles south of the De Kalb boundary, a well record gives sandstone as the bed rock.

The information concerning the deeper strata is from the records at De Kalb and Sycamore. The same geological succession is present as noted in other wells of this area; however, the Prairie du Chien limestone is thicker and not so sandy as at Rockford and Belvidere. The series of strata is more closely comparable to that found in the wells to the east.

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[1] Leverett, Frank, op. cit. p. 600.

Underground Waters

SOURCES

Although the mantle of drift is very heavy in this county it does not form so good a collecting reservoir for the rainfall as does the deposit overlying the area to the east and north, because the drift in De Kalb County as a whole is less sandy than that in the counties to the north and east. This does not mean, however, that no intercalated sand beds are found in the drift of this area.

The shallow wells in the northwest townships where the drift is thin are usually not over 50 feet deep. Around De Kalb and Sycamore the shallow wells average 100 feet in depth and obtain water from sand beds in the drift. It is in most places possible to obtain 10 to 25 gallons per minute from wells 3 to 4 inches in diameter. The water level is from 45 to 60 feet below the surface. Most of the farm wells in the remainder of the county are over 100 feet in depth and many are continued to the bed rock, which in some places is at depths of over 200 feet.

Flowing drift wells are rare, but they have occasionally been obtained along the bases of terminal moraines that act as collecting areas. A few of these have been struck in the southeastern part of T. 37 N., R. 3 E. The terminal moraine to the northwest is probably the collecting area. A few flowing wells have also been obtained along South Kishwaukee River in the vicinity of Sycamore.

The larger supplies of water, as for the cities and villages, are obtained from wells which penetrate the St. Peter sandstone or lower strata. These range from 500 to 1,330 feet in depth and yield sufficient quantities of good water.

There are no flowing deep wells in the county, although the level in the new well at Sycamore is but 17 feet below the surface. No exact information could be obtained regarding the lowering of the water table. Mr. Russell, City Engineer at De Kalb, said that the water table had not lowered over a foot per year. The present level in the "Potsdam" wells is 104 feet below the surface. Mr. Leverett in his report of 1899 gave the level in the St. Peter well at about 65 feet below the surface; this well has since been deepened to the "Potsdam" strata so that it is not possible to determine the static head of the St. Peter water. There has been very little if any lowering of the St. Peter static head at Sycamore in the past ten years.

CHEMICAL CHARACTER

All of the waters analyzed are from the deeper wells. They are only moderately mineralized and are used for boiler purposes. The analyses from the different localities are appended.

LOCAL SUPPLIES

DE KALB

Excellent data concerning the underground formations at De Kalb have been obtained from the examination of two sets of drillings from wells which are over a mile apart. The two records are from wells at the city waterworks and at the east plant of the American Steel and Wire Company. The records are essentially the same, except that the St. Peter sandstone is about 60 feet thicker in the well of the American Steel and Wire Company. The record of the city well only is here published. The dolomite found in the upper part of the St. Peter sandstone between 580 and 595 feet is unusual at this position, but a similar thickness of dolomite was found intercalated in the upper part of the St. Peter in the city well at practically the same depth. In Missouri and Arkansas calcareous beds are in places developed in a series of sandstones, the topmost of which is the typical St. Peter.

It is interesting to note that a heavy sandstone which is overlain by glauconiferous dolomite is struck at 1,140 feet. Such a glauconiferous bed overlying a heavy sandstone was found at Rockford, Dixon, Batavia, Lake Forest, Joliet, and Chicago.

The city water supply is furnished by three wells, each of which is practically 1,300 feet in depth. There is also an old 800-foot well that is rarely used. The well drilled in 1912 has 156 feet of 16-inch O. D. surface pipe and is finished at 8 inches. This well tested over 300 gallons per minute in 1912. The other two wells are probably somewhat smaller. All the deep wells are equipped with electrically driven, deep-well pumps. The average daily pumpage in 1913 was 363,500 gallons. The water level in April, 1912, was 104 feet below the surface; no recent measurements have been made, but Mr. Russell, City Engineer, believes the recession has been less than a foot per year.

The water level in the new 1,330-foot well of the American Steel and Wire Company is 128.5 feet below the surface. This level is comparable to that at the city well when it is considered that the ground elevation at the Steel Company is about 25 feet above that at the city waterworks. A 3-hour pumping test made on the 1,330-foot well shortly after it was completed gave a yield of 300 gallons per minute. The water level receded 58.5 feet, or to a depth of about 187 feet. This well has a 16-inch O. D. surface pipe and is finished at about 8 inches. There are two other wells owned by this company which are approximately 800 feet in depth. The yield from each is about 100 gallons per minute.

The Chicago and North Western Railway Company has a 1,003-foot well that furnishes water for the locomotives.

Log of the De Kalb City Well in SE. 1/4 sec. 22, T. 40 N., R. 4 E.

Elevation—865± feet

Completed April 15, 1912

Generalized section

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Clay, sand, and gravel	150	150
Ordovician system		
Galena-Platteville limestone		
Dolomite, light-gray to gray, subcrystalline	374	524
St. Peter sandstone		
Sandstone, well rounded, colorless quartz sand	281	805
Sandstone, light reddish-brown in color due to the cementing material	30	835
Prairie du Chien limestone		
Chert, siliceous oolite, and reddish-brown shale	45	880
Dolomite, light-gray to gray, subcrystalline	125	1005
Dolomite, light-brown or brownish-gray, finely crystalline, containing an occasional speck of a green mineral, probably glauconite	10	1015
Dolomite, containing a noticeable amount of very fine quartz sand, besides minute grains of glauconite. The dolomite is reddish-brown and finely crystalline	30	1045
Dolomite, sandy, light reddish-brown. The sand consists of fine, angular or subangular, quartz grains. The dark-green glauconite grains are conspicuous	25	1070
Sandstone, dolomitic, light-green due to the presence of a large amount of glauconite. The sand consists of fine, subangular or angular, quartz grains	20	1090
Shale, red, contains some dolomite, glauconite, and quartz sand	5	1095
Sandstone, light reddish-green to green	25	1120
Sandstone, slightly dolomitic and glauconitic. The sand consists of fine, subangular to slightly rounded, colorless quartz grains	60	1180
Cambrian system		
"Potsdam" group		
Sandstone, fine to medium in size, rather well rounded, colorless, quartz sand	126	1306

The last sample contains some pieces of a green or greenish-gray shale, which seems to indicate that this shale was struck at a depth of about 1306 feet.

GENOA

The municipal water supply is obtained from a 1,500-foot well in a "Potsdam" sandstone. The well has a surface diameter of 12 inches

and is finished at 6 inches. The water level at rest is 50 feet below the surface and a 24-hour pumping test at the rate of 200 gallons per minute failed to lower the level more than 2 feet. The surface elevation is about 825 feet. The average daily consumption is 50,000 gallons.

The water is reported to have a slight sulphur odor and taste when first pumped. The analysis of the water indicates the presence of calcium and magnesium carbonate, but not in excessive amounts.

HINCKLEY

The village water supply is obtained from a 708-foot well in the St. Peter. The surface diameter is 12 inches, and it is probably finished at 8 or 10 inches. The water level in 1913 on the completion of the well was 4 feet below the surface. In a pumping test of about an hour at the rate of 250 gallons per minute, the level lowered 24 feet. The surface elevation is approximately 740 feet.

The following succession was reported in a well at a nearby tile factory: 80 feet of drift, mainly clay, about 300 feet of limestone, and the remaining depth sandstone. The appended analysis indicates a rather soft water when the depth of the well is considered.

KIRKLAND

The village supply is obtained from a shallow well, the exact depth of which is not known.

MALTA

A driller's log has been obtained of the well owned by the Chicago and North Western Railway Company at Malta.

Record of Chicago and North Western Railway well at Malta

Elevation—915± feet

(Authority: J. P. Miller Artesian Well Company, Chicago)

Description of strata	Thickness *Feet*	Depth *Feet*
Clay, sand, and gravel	245	245
Limestone	210	455
Limestone, sandy	2	457
Sandstone	18	475
Shale, sandy	2	477
Shale, gray	23	500
Sandstone (*St. Peter*)	321	821
Marl, red	4	825
Sandstone	25	850
Marl, red	4	854
Marl and limestone streaks	66	920
Sandstone	50	970
Shale	5	975
Marl, red	35	1010

SANDWICH

The geological succession at Sandwich, as given in the driller's log, indicates a sandy horizon about 20 feet thick below the drift. There is also present at a depth of 397 feet a sandstone which is 99 feet in thickness. It is probable that this latter sandstone is the St. Peter, although if this is correct a very steep dip is indicated between Somonauk and Sandwich.

Log of the city well at Sandwich

Elevation—667± feet

(Authority: J. P. Miller Artesian Well Co., Chicago)

Description of strata	Thickness *Feet*	Depth *Feet*
Clay, sand, and gravel	131	131
Soft, "shelly" rock	4	135
Sandstone, fine; in streaks	2	137
Soft, "shelly" rock	1	138
Sandy limestone	14	152
Limestone, brown, "shelly"	2	154
Limestone, hard	8	162
Limestone	128	290
Marl, red	5	295
Shale, green	102	397
"Quartz" rock	18	415
Sandstone	181	596
Shale	4	600

The source of the municipal water supply at Sandwich is three wells, two of which are 120 feet in depth and 8 inches in diameter; the third well, which was drilled in 1911, is 600 feet deep and is 12 inches in diameter at the surface. The water level is reported to be 17 feet below the surface. The two shallow wells flowed until 1910 when it became necessary to pump them. These 120-foot wells are only 2.5 feet apart.

SOMONAUK

The St. Peter sandstone seems either to underlie the drift at this locality or to be covered by only a very thin capping of Galena-Platteville limestone. The record of the strata in the village well is given.

Log of village well at Somonauk

Elevation—690± feet

(Authority: J. P. Miller Artesian Well Co., Chicago)

Description of strata	Thickness *Feet*	Depth *Feet*
Soil, "hard pan," stones, and gravel	?	?
Sandstone and limestone	?	106
Sandstone, white (*St. Peter*)	46	152
Shale, sandy	21	173
Shale, "flinty"	52	225
Limestone	235	460
Shale	10	470
Limestone	32	502

SYCAMORE

The geological succession at Sycamore down to a depth of 1,000 feet is indicated by the accompanying log. The St. Peter sandstone has a thickness of 280 feet and is the main water-bearing formation for the city wells. It is very probable, however, that considerable water is also obtained from the overlying limestones.

The city waterworks is located near the business section, but the well drilled in 1914 is located about three-quarters of a mile north of the old station. The two old wells are about 900 feet deep and are about 20 feet apart. The diameters are 10 inches at the surface and 6 inches at the bottom. Well No. 1 has 170 feet of surface casing and well No. 2 has 192 feet. The yield per well ranges up to 275 gallons per minute.

The water level at rest in 1907 was 47 feet below the surface; no other measurements have been made. In the well drilled in 1914 the water level is only 17 feet below the surface, but the ground elevation is about 30 feet below that at the old wells. This would seem to indicate that there probably has been only a very slight lowering of the water table in the past ten years.

Log of City Well, Sycamore, NE. 1/4 sec. 32, T. 41 N., R. 5 E.

Elevation—810± feet

(Drilled in 1914 by W. L. Thorne & Co., Platteville, Wis.)

Generalized section

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Glacial till; soil, sand, and gravel	150	150

Log of city well, Sycamore—Concluded

Description of strata	Thickness *Feet*	Depth *Feet*
Ordovician system		
Galena-Platteville limestone		
Dolomite, gray	355	505
Dolomite, somewhat shaly	30	535
St. Peter sandstone		
Sandstone, colorless, rounded quartz sand	280	815
Prairie du Chien group		
Dolomite, gray	95	910
Dolomite, gray; some glauconite grains	92	1002

The analysis of the water from well No. 1 is appended. There is no great amount of dissolved mineral matter, and the water is used for boiler purposes. Only a very slight trace of hydrogen suphide was noted, but at times it is reported to be more noticeable. The temperature of the water direct from the pump was 51.5° F., which is very low for waters from this depth. It is therefore probable that considerable additions are received from waters in the upper strata.

The pumping equipment had not yet been installed for the recently drilled well, but a few hours' test gave a yield of 300 gallons per minute and a recession of 49 feet in the water level. This well is 1,002 feet in depth, cased with 143 feet of 12-inch pipe, and finished at 6 inches. The total cost of drilling and casing was $2,650.

DU PAGE COUNTY

Physiography

Du Page County is situated immediately west of the middle portion of Cook County and has a total area of 345 square miles. The geology and physical features of the greater part of this area is described in detail by A. C. Trowbridge.[1]

The entire county is overlain by a heavy deposit of drift, the geologic age of which is comparatively recent. This mantle has essentially obliterated the topography of the underlying bed rock.

A terminal moraine extends southward across the western part of the county, the ridge having a width varying from less than a mile to nearly three miles. This strip of higher land extends southward from a point just west of Bartlett, Cook County. The moraine passes through the eastern half of West Chicago and two and a half miles north of Naperville becomes indistinguishable from the ground moraine.[2] The average elevation along the crest is from 780 to 800 feet, or about 20

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[1] Trowbridge, A. C., Geology and Geography of the Wheaton Quadrangle: Ill. State Geol. Survey Bull. 19, 1912.

[2] Trowbridge, A. C., Idem, p. 21.

to 30 feet higher than the surface of the ground moraine to the east, and 30 to 40 feet above its surface to the west.

The remainder of the county outside of the strip of terminal moraine is covered by the ground moraine. The topography on the whole is of an undulating type, consisting of low elevations with gentle slopes, ill-defined ridges, and broad, shallow depressions. The relief is slight, probably not averaging over 30 feet, although the difference in elevation between the East Branch of Du Page River and the bordering uplands some miles away is over 100 feet. The valley of this stream is about 50 feet deep and is the most noticeable topographic feature in the area. Small areas with a relief of less than 10 feet are found in a few places. Most of these level tracts are surrounded by areas characterized by the undulatory topography.

The major drainage of the county is effected to the south through the East and West branches of Du Page River and Salt Creek. All these streams are tributaries of Desplaines River. Along the extreme western border of the county a few small creeks drain westward to Fox River. The entire area, like most regions overlain by recent glacial deposits, is poorly drained; marshes, swampy depressions, and even small ponds existed originally in considerable numbers, but lately the drainage has been much improved by tiling and ditching. In a region of this nature, where drainage lines are poorly developed and the deposit of porous, surface material is heavy, the run-off is not great, and the larger part of the rainfall sinks into the ground, bringing about conditions very favorable for shallow wells.

Geology

The entire area, except for small outcrops of the bed rock at Naperville and Elmhurst, is covered by a mantle of drift, which in many places is over 100 feet thick. The greatest thicknesses appear to occur in Bloomingdale Township, which is the middle one of the northern tier, where records of nearly 180 feet to bed rock have been obtained. The drift thins gradually to the east. The thickness at Wheaton is from 90 to 105 feet; in the Glen Ellyn village well and at Downers Grove it is about 100 feet.

The bed rock formation underlying this region is exposed at only two places, Naperville and Elmhurst. The quarries at these localities where it is known as the Niagaran limestone, show that it is a gray dolomitic limestone. Well drillings in other parts of the county have indicated that this formation is the bed rock. Dr. Weller[1] has shown

[1] Weller, Stuart, A peculiar Devonian deposit in northeastern Illinois: Jour Geol., vol. 8, p. 483, 1899.

that deposits younger than the Niagaran limestone at one time covered this area, by his discovery of Upper Devonian shale in crevices of the Niagaran limestone in the quarry at Elmhurst. It is probable that the greater part of this younger formation, except for such remnants favorably situated for preservation, had been removed by erosion before the deposition of the glacial drift. However, the glacier itself may have removed much of this soft deposit.

The deeper-lying formations explored by drillings are indicated in the records from Bensenville, Elmhurst, West Chicago, and Downers Grove. The general succession, except for variations in depths and thicknesses, is similar to that found in other parts of northeastern Illinois. The strata have a southeastward dip of about 10 feet per mile. Therefore, provided there are no differences in surface elevations, the formations will be nearer the surface in the northwest part of the county than in the southeast corner.

Underground Waters

SOURCES

The mantle of drift covering the county forms a good collecting reservoir for the rainfall. It is therefore possible in most parts of the area to obtain good shallow wells either from the drift or in the upper part of the underlying bed rock; especially is this true in the eastern part of the county, where the surface elevations are about 100 feet lower than the terminal morainic area a few miles to the west. The drift at Elmhurst and Hinsdale is not thick, but the underlying limestone contains water-bearing crevices.

Wells 1,000 or more feet deep have been sunk at Naperville, Downers Grove, and Bensenville. Wells in any part of the county exceeding 1,650 feet in depth will be strong producers. Although deeper wells have been drilled, in most cases it has not been necessary.

A great number of deep wells has not been drilled in the county, so that there are very few data in regard to the static head. Further, the walls in some of the older wells may have caved so badly that the level is only that of the shallow, underground water table and not the true static head of the deep artesian waters.

The static head of the "Potsdam" waters at the Chicago, Milwaukee, and St. Paul wells at Bensenville was 60 feet below the surface in 1913 or at an altitude of 620 feet, as the curb elevation is about 680 feet. At Downers Grove the water level is 90 feet below the surface or at an altitude of approximately 627 feet; this compares favorably with

the head at Bensenville. The static head of the St. Peter water at Elmhurst was 36 feet below the surface or at an altitude of about 641 feet. However, there is a possibility that this may not be the true St. Peter head but modified by that of the water from the bed rock or Niagaran limestone which in this locality contains large amounts.

The water level in the 1,375-foot well at Naperville is only 14 feet below the surface, but it is known that a large stream of water enters the well at 45 feet below the surface. It is therefore probable that the static head refers to the Niagaran limestone water and not to that of the deeper strata. The curb elevation is about 677 feet.

The only information on the recession of the water table was obtained at Bensenville. In 1911 the static head of the first well drilled was 41 feet below the surface. The final wells completed in 1913 had a static head of 60 feet below the surface which is a lowering of about 19 feet. The water levels at present are not known.

CHEMICAL CHARACTER

The mineral content of the waters at the different localities is indicated in the appended analyses. There is usually considerable variation in the chemical character of the water from the drift and Niagaran limestone. In general, the waters are rather hard and the predominating salts are the bicarbonates of calcium and magnesium, with often a considerable amount of magnesium sulphate. A soft water has been obtained at Bensenville by casing to a depth of about 1,250 feet or to about the top of the first "Potsdam" sandstone, as shown in the description of the well waters at that locality.

LOCAL SUPPLIES

BENSENVILLE

The Chicago, Milwaukee, and St. Paul Railway Company has drilled at least four deep wells at their Godfrey yards near Bensenville. The strata penetrated are indicated by the following log which has been compiled from the driller's record.

Log of Chicago, Milwaukee & St. Paul Railway Co. well No. 2, Bensenville

Elevation—680 feet

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent deposits		
Surface sand, gravel and clay...........................	77	77
Silurian system		
Niagaran limestone		
Limestone	193	270

Log of C. M. & St. P. Ry. Co., Bensenville—Concluded

Description of strata	Thickness *Feet*	Depth *Feet*
Ordovician system		
Maquoketa shale		
Shale, blue	200	470
Galena-Platteville limestone		
Limestone	100	570
Limestone, contains crevices and "caves" slightly	15	585
Limestone	220	805
St. Peter sandstone		
Sandstone	245	1050
Prairie du Chien group		
Limestone, sandy	115	1165
"Red-Rock"	40	1205
Limestone	25	1230
Shale	2	1232
Limestone	28	1260
Cambrian system		
"Potsdam" group		
Sandstone	200	1460
Limestone and shale	240	1700
Sandstone	100	1800
Limestone	16	1816
Sandstone, brown	89	1905
Sandstone, red	140	2045
Sandstone, hard, red	139	2184
Sandstone, soft, white	5	2189
Sandstone, hard, red	12	2201

Water was desired of which the mineral content was sufficiently low to permit its use in locomotives, and hence in drilling the first well, samples of water were collected at the different horizons and analyzed. The waters from depths below 1,450 feet were found to contain smaller amounts of scale-forming solids than those from the upper strata. The analyses made by the Chicago, Milwaukee, and St. Paul Railway Company of the waters from the different depths are given in Table 9. Another analysis made by the State Water Survey is given in the appendix. It is seen that the waters from the greater depths are characterized by the alkali salts, whereas the bicarbonates of calcium and magnesium and magnesium sulphate are present in only small amounts. These latter scale-forming salts are present in the waters from the lower Prairie du Chien group, St. Peter sandstone, and the upper strata. There is a noticeable increase in the mineral content of the waters below depths of about 2,000 feet; the alkali chlorides, particularly of sodium, occur in considerable amounts.

These wells were drilled to a depth of about 2,250 feet and cased to about 1,250 feet which is just above the first sandstone of the

"Potsdam" group. Well No. 2 has a depth of 2,201 feet; the surface casing is 12 inches in diameter and extends to a depth of 251 feet, below which a 6-inch casing extends to a depth of 1,231 feet where it is sealed with hydraulic cement. The diameter of the remainder of the hole is 6 inches or slightly less. The final test on well No. 2 was made April 15, 1913, and 170 gallons per minute were obtained. The water level at the commencement of pumping was 61 feet below the surface and at the end of 7 hours continuous operation it had lowered to 92 feet. Practically the same test results were obtained from the other wells.

The wells at Bensenville are somewhat similar to those of the Chicago and North Western Railway Company at Proviso, about 4 miles to the southeast. The wells at Proviso are cased to greater depths.

The analyses in Table 9 indicate that softer waters are present in this locality at the lower horizons. However, the supply is limited, so that wells cased to depths of 1, 250 feet do not deliver so large quantities as wells in which the upper waters have not been shut out.

DOWNERS GROVE

The geological succession at Downers Grove is indicated by the following driller's log.

Log of city well at Downers Grove
Elevation—717± feet
(Authority: J. P. Miller Artesian Well Co., Chicago)

Description of strata	Thickness *Feet*	Depth *Feet*
Clay, sand, and gravel	83	83
Limestone	187	270
Shale	65	335
Limestone	45	380
Shale	100	480
Limestone	337	817
Sandstone (*St. Peter*)	223	1040
Marl and shale, "caves"	20	1060
Limestone	55	1115
Marl, red	23	1138
Limestone	152	1290
Sandstone	43	1333
Shale	75	1408
Limestone, sandy	27	1435
Sandstone, hard	60	1495
Sandstone, soft	110	1605
Limestone and shale	25	1630
Shale	40	1670
Shale, sandy	85	1755
Shale, blue; streaks of lime	85	1840
Limestone	60	1900
Shale	5	1905
Sandstone	116	2021

TABLE 9.—*Analyses of waters from the Chicago, Milwaukee and St. Paul Railway wells at Bensenville*

Compounds	Grains per U. S. gallon													
	1		2		3		4		5		6		7	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Calcium carbonate	.97	1.95	2.94	3.26	5.34	5.34	6.64	6.64	10.22	13.12	6.90	6.90	8.21	8.21
Calcium sulphate	4.48	3.15	4.61	4.13	....	....	....	....	3.95	....	....	....	....	....
Magnesium carbonate	.83	....	.27	....	2.10	2.10	2.87	2.87	3.88	1.45	4.04	4.04	3.48	3.48
Magnesium sulphate	....	1.18	....	.44	....	....	....	....	....	3.48	....	....	....	....
Alkali carbonate	....	....	....	....	7.81	7.81	8.92	8.92	....	....	2.97	2.97	2.77	2.77
Alkali sulphate	6.74	6.74	7.47	7.47	10.50	10.50	4.82	4.82	3.17	3.17	11.71	11.71	45.03	45.03
Alkali chloride	2.99	2.99	3.38	3.38	4.68	4.68	12.44	12.44	50.96	50.96	3.18	3.18	2.89	2.89
Oxides (undetermined)	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Incrusting solids	6.28	6.28	7.82	7.83	7.44	7.44	9.51	9.51	18.05	18.05	10.94	10.94	11.69	11.69
Non-incrusting solids	9.73	9.73	10.85	10.85	22.90	22.90	26.18	26.18	54.13	54.13	17.86	17.86	50.69	50.69
Total residue	16.01	16.01	18.67	18.68	30.34	30.34	35.69	35.69	72.18	72.18	28.80	28.80	62.38	62.38

A Analysis made by the Chicago, Milwaukee and St. Paul Railway Company. B Re-calculation by the State Water Survey.

1. Well No. 1 at Bensenville. Sampled while drilling, at depth of 1,450 feet. Oct. 29, 1912.
2. Do. Sampled at 1,150, one hour after drilling stopped. Oct. 29, 1912.
3. Do. Sampled at 2,030 feet, while drilling. Nov. 23, 1912.
4. Do. Sampled at 2,128 feet, while drilling. Nov. 29, 1912.
5. Do. Sampled at 2,290 feet. Cased to 1,236 feet. Dec. 13, 1912.
6. Well at Godfrey yards, near Bensenville. Depth 1,833 feet. Cased to 1,196 feet. June 28, 1911.
7. Do. Dec. 30, 1912.

The deep well is 10 inches in diameter at the surface and 6 inches at the bottom; the approximate yield is 175 gallons per minute. The water level at rest in 1913 was 90 feet below the surface or at an altitude of approximately 727± feet; the effects of pumping are not known.

There is also a 250-foot Niagaran limestone well that delivers about 75 gallons per minute. The temperature of the water was 50.2°F. after it had passed through the deep-well pump.

The analysis of the shallow-well water is given in the appendix and indicates a notable amount of hardness. There is no analysis of the deep-well water.

The Chicago, Burlington, and Quincy Railroad Company has a 150-foot well 12 inches in diameter, which is cased about 77 feet to bed rock. The yield on a test was 150 gallons per minute and the average pumpage is 100 gallons. The water level is 62 feet below the surface; the effects of pumping are not known.

ELMHURST

The city of Elmhurst completed a 950-foot well in 1915. Samples of drillings were collected at short intervals under the direction of Mr. Emerson, consulting engineer for the city. These have been studied by the writer and a generalized section compiled from the detailed record is given below.

This well has about 75 feet of 18-inch surface pipe and 93 feet of 10-inch, the bottom of which is at a depth of 633 feet. A pumping test yielded 152 gallons per minute when a depth of 301 feet had been reached; the head of water dropped from 27 feet below the surface to 29 feet.

Below the depth of 538 feet, crevices were found in the Galena-Platteville limestone through which water was escaping as shown by a 15-foot drop in water level at that depth. To shut these off 93 feet of casing, sealed at the top and bottom, was placed at this horizon, which increased the head 8 feet.

A pumping test made after the well was completed and before the casing was placed gave a yield of 325 gallons per minute; the water dropped from 44.8 feet below the surface to 53 feet. Another test made after the cervices were cased off gave a yield of 410 gallons per minute for 8 hours; the water dropped from 34.6 feet to 45.5 feet.

The analyses taken at the various depths as given in the appendix are very similar. A large amount of this water is from the Niagaran limestone. The absorbing area is the higher region to the west.

Log of Elmhurst city well in sec. 1, T. 39 N., R. 11 E.

Elevation—677± feet

Generalized section

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Soil, sand, and gravel (No samples)	...	....
Silurian system		
Niagaran limestone		
Dolomite, light gray to gray, subcrystalline	180+	260
Ordovician system		
Maquoketa shale		
Shale, dolomitic, greenish gray	80	340
Dolomite, gray	10	350
Shale, gray, darker in color than the shale between 260 and 340	100	450
Galena-Platteville limestone		
Dolomite, light gray to cream-colored gray, subcrystalline	340	790
St. Peter sandstone		
Sandstone, colorless, rounded quartz sand averaging .3 to .5 mm. in diameter	100	890
Prairie du Chien limestone		
Dolomite, light gray, subcrystalline, some sand and white chert	68	958
Still in Prairie du Chien limestone at completion of well		

EOLA

The Chicago, Burlington, and Quincy Railroad Company has a 165-foot well which furnishes a good boiler water. The 12 inch casing extends to bed rock at a depth of 131 feet. The water level is 25 feet below the surface or at an altitude of 790 feet. The well has a tested capacity of 175 gallons per minute.

GLEN ELLYN

The city of Glen Ellyn has an 8-inch well 310 feet in depth. The drift is 114 feet thick, and the remainder of the depth is in Niagaran limestone. The pumpage is by an air-lift system, and the yield is 275 gallons per minute. The water level is 43 feet below the surface and recedes to 56 feet during pumping. The average daily consumption is 83,600 gallons.

The water is moderately hard and similar to that obtained from other shallow wells in the county.

HINSDALE

The city of Hinsdale is situated along the eastern border of the Valparaiso morainic area. The elevated region to the west has a thick mantle of drift and the drainage is so inadequate that large quantities of shallow, underground water are collected. This water is not all held in the drift, as a great deal of it finds its way down to the bed rock where it probably has developed water channels. The underground-water table has a slope to the east similar to that of the land surface, although not so great. The above conditions probably account for the large supplies of water available in Hinsdale at shallow depths.

The municipal supply is furnished by two wells that are 268 feet deep. The diameters are either 12 or 10 inches. The pumpage is by two suction pumps each of which has a daily capactiy of 2,000,000 gallons. These pumps are placed in pits 20 feet deep; the water level is 20 feet below the floor of this pit. The depression of the water table while pumping is not known. The average daily pumpage is 300,000 gallons.

The water is rather hard and a softening plant was installed during the summer of 1915. The analysis given is of the untreated water.

The temperature of the water from the pump was 52.5°F. which is similar to that of other Niagaran limestone wells in the county. A temperature of 50.8°F. was recorded at Lombard and 51.5° for the spring water at Naperville. These latter figures are probably very close to the average temperature of the shallow well waters.

LOMBARD

The village water supply is furnished by a well 89 feet in depth. There is no record of the depth to bed rock and it may not have been reached. The well is operated only a few hours per day, during which time the yield is over 300 gallons per minute. The water level at rest is 26 feet below the surface and drops 3 feet during pumping.

The water is moderately hard and would form some scale if used untreated in boilers. The principal salts are the bicarbonates of calcium and magnesium.

NAPERVILLE

The city of Naperville has a 1,375-foot well which is the source of the municipal supply. There is no log of this well, but the accompanying record is that of an old well less than 50 feet away.

Log of old city well at Naperville

Elevation—677± feet

Description of strata	Thickness *Feet*	Depth *Feet*
Loam and loose rock	20	20
Limestone	95	115
Limestone streaked with shale	190	305
Limestone	341	646
Sandstone (*St. Peter*)	129	775
Limestone streaked with shale	61	836
Limestone	100	936
Shale	3	939
?	6	945
Sandstone	5	950
Limestone	315	1265
Sandstone	155	1420
Sandstone, "dirty"	5	1425

The surface diameter of the 1,375-foot well is 12 inches and it is 8 inches at the bottom. The water level at rest is 14 feet below the surface or at an altitude of about 663 feet. When pumping at the rate of about 250 gallons per minute the level recedes 71 feet. It is very probable that this level does not represent the true static head of the "Potsdam" water, but that it is influenced by seepage from the Niagaran limestone. This well is cased only to a depth of about 14 feet, and at 45 feet a large water-bearing crevice was penetrated.

The water is rather hard and would form considerable scale if used untreated in boilers. The analysis of a spring water at Naperville is also given; the mineral content is somewhat greater than the city water, but there is no radical difference in the chemical composition. A number of springs are found along both branches of Du Page River.

WEST CHICAGO

The city water supply is furnished by two 12-inch wells which are 775 and 322 feet in depth; the bottom diameters are probably 8 inches. The depth to bed rock is reported as 89 feet. The yield from each well is about 100 gallons per minute. The water level is 50 feet, and there has not been over a foot recession during the past five years. The lowering during pumping is not known.

The Chicago and North Western Railway Company has two wells at West Chicago; one, drilled in 1890, is 2,081 feet in depth, and another is approximately 30 feet. The driller's log of the deep well is given below.

Log of Chicago and North Western Railway Company well at West Chicago

Elevation—740± feet

Description of strata	Thickness *Feet*	Depth *Feet*
Soil, clay, sand, and gravel	42	42
Clay	5	47
Gravel	3	50
Clay	15	65
Gravel	29	94
Limestone	249	343
Limestone "shell rock"	45	388
Limestone	336	724
Sandstone *(St Peter)*	310	1034
Marl, red; "caves"	71	1105
Limestone, shale, and marl	190	1295
Sandstone	240	1535
Limestone	231	1766
Sandstone	234	2000
Sandstone; "drillings flow away"	81	2081

The deep well delivers about 100 gallons per minute, but it is very probable that much of this water is from the Niagaran, for the well is old and may have caved at the lower depths. The analysis indicates a water similar to that from other wells in the county which penetrate the Niagaran limestone. The dug well obtains a large quantity of hard water from a sand and gravel stratum in the drift.

Several other rock wells within the city giving good yields are owned by the Union Tool Company, the Borden Condensed Milk Company, and the West Chicago Sash and Door Company.

WHEATON

The city of Wheaton obtains its water supply from two 10-inch wells 175 feet in depth. There is 110 feet of drift and the remainder of the depth is in limestone. The wells are 14 feet apart and a 34-foot shaft, 5 feet in diameter, is placed between them. At the bottom of this shaft the two wells are connected and a centrifugal pump delivers the water to the surface. The combined pumpage from both wells is about 680 gallons per minute for about 8 hours per day. The water level at rest is about 22 feet below the surface and drops approximately 18 feet at the above rate of pumping. A delivery of 794 gallons per minute has been obtained on a test with an approximate drop of 24 feet.

The water level is reported to have remained practically stationary for 26 years. During the dry season of 1914 there was a lowering of 6 inches, but the normal water level returned after the first rains. The high level of the shallow ground-water table as compared with the rapidly receding water table of the "Potsdam" formations in Chicago

and other parts of northeastern Illinois strongly suggests that wherever it is possible in this area to develop the shallow water resources it should be done in preference to sinking deep wells.

The water is a moderately hard calcium and magnesium carbonate water satisfactory for boiler use after slight treatment.

GRUNDY COUNTY

PHYSIOGRAPHY

Grundy County is situated east of La Salle County and west of Will and Kankakee counties. The total area is 433 square miles.

The county has a plain-like topography; the relief is slight, except in the west-central part along Illinois River where some bluffs have been developed. The Marseilles terminal moraine conforms roughly to the outline of the county on the north, west, and south.

The Illinois has cut through this elevated belt at Marseilles and thus effected an outlet for its waters. There is a gradual slope of the land surface from this crescent-shaped ridge to the headwaters of the Illinois in the northeastern township. There are a few dunes in the eastern part of the county.

The Illinois crosses the northern part of the county in a westward direction. However, because of the Marseilles terminal moraine, the tributaries in this area flow eastward. Those north of the Illinois have a southeastward course, and those on the south, northeastward.

Geology

Essentially the entire county is covered by bluish drift that is very thin in the eastern part, but increases to over 100 feet along the western border. In the eastern portion of the county, southeastward from Morris and in the vicinity of Braceville and Coal City, sand deposits overlie the drift. This sand was probably deposited by a glacial lake that occupied the basin at the headwaters of the Illinois.[1] The sand is usually only a few feet in thickness, but in some places the winds have shaped it into dunes.

The bed-rock underlying the greater part of the county belongs to the Pennsylvanian series. In the northeastern part of the county the Maquoketa shale underlies the drift over a small area.

The Pennsylvanian, as here developed, consists primarily of shales, sandy shales, thin sandstones, and a small amount of coal. These

[1] Leverett, F., The Illinois Glacial Lobe: U. S. Geol. Survey, Monograph 38, p. 315, 1899.

strata outcrop along the Illinois in the western portion of the county and also in the vicinity of Coal City.

The strata underlying the Pennsylvanian are indicated by the logs from Morris, Mazon, and Coal City.

Underground Waters

SOURCES

The most favorable conditions for shallow, drift wells are found along the west border of the county, Here the drift is heavy, and the higher morainic area to the west furnishes a good absorbing area. This usually creates sufficient hydrostatic pressure to bring the ground water near to the surface. In the townships south of the Illinois the most of the wells do not penetrate below the drift, as the water from the underlying Pennsylvanian system is usually sulphurous.

The St. Peter sandstone is the important water-bearing formation along Illinois Valley and in the townships to the north. The depth to this sandstone varies from less than 200 feet in the eastern part of the county to over 600 feet in the northeastern townships. In the southern and southwestern parts of the county, the depths to this formation are not known. At Mazon, the depth is probably about 620 feet.

Flowing wells from the St. Peter sandstone are obtained at low altitudes along the Illinois. The city well at Morris flowed in 1894 when it was drilled; the present head is 48 feet below the surface or at an altitude of about 455 feet. In Goose Lake Township, flowing wells are obtained from the "Coal Measures," Galena-Platteville limestone and St. Peter sandstone; the surface elevations are low—about 520 feet.

A 2,100-foot well at Minooka has a good flow at an elevation 4.5 feet above the surface; when this well was drilled in 1886 the head was reported to have been 46 feet above the surface, or at an altitude of 660 feet.

CHEMICAL CHARACTER

The water obtained from the drift wells contains a moderate amount of dissolved mineral matter, generally in the form of carbonates of calcium and magnesium, and sulphate of magnesium. In the southern part of the county, which is underlain by the Pennsylvanian, or "Coal Measures," the water in most of the wells that penetrate these strata contains hydrogen sulphide. The sulphates and chlorides of sodium are generally also present in notable amounts.

The St. Peter water in the northern half of the county is not excessively mineralized and the hydrogen-sulphide content is low. There

are no definite data concerning the character of the St. Peter water in the southern townships, but it probably has a rather high mineral content. The St. Peter wells should be completely cased down to the top of this formation, in order to shut out all of the upper, highly mineralized waters.

The waters from depths of 1,900 feet and greater are highly mineralized, as indicated by the analyses from Minooka and Carbon Hill.

LOCAL SUPPLIES

BRACEVILLE

The village has a dug well, or pit, which is 12 by 14 feet to a depth of 18 feet, below which it is 6 feet square to a depth of 24 feet. The water is used only for fire protection and not as a source of public supply. Formerly there was a deep rock well, but this became plugged during an attempt to enlarge the hole, and had to be abandoned. There are many driven wells in the village 12 to 14 feet deep which draw water from the sand.

CARBON HILL

The village water supply is furnished by a 1,900-foot well drilled about 1893. Formerly the water flowed directly into the mains with sufficient pressure to render pumping unnecessary. However, the static head gradually decreased, so that in 1900 the well was equipped with a pump. The present water level at rest is 20 feet below the surface, or at an approximate altitude of 545 feet. The recession while pumping has not been determined. The average daily pumpage is probably 8,500 gallons.

The water is hard and contains a large amount of dissolved mineral matter. The high sodium-sulphate content gives the water a taste that is unpleasant to many people. The water has little, if any, hydrogen sulphide, in which it differs from that obtained from the shallow well at Coal City about a mile to the southeast.

COAL CITY

The municipal supply is derived from a 350-foot well drilled in 1892. A 7-inch casing extends from the surface to a depth of 285 feet, which is reported to penetrate limestone for 15 feet. The remainder of the depth is thought to be in limestone. When the well was drilled, the static head was 5 feet above the surface, but in August, 1914, it was 32 feet below the surface. The level was reported to be 46 feet in Sep-

tember, 1915, while pumping was going on at the rate of 180 gallons per minute. The curb elevation is approximately 562 feet. The average daily consumption is 220,000 gallons.

The analysis of the water indicates a hard water with a high mineral content. The presence of a large amount of hydrogen sulphide gives a sulphurous taste.

A driller's log of the Elgin, Joliet and Eastern Railway Company's well is given below.

Driller's log of Elgin, Joliet and Eastern Railway well at Coal City

Elevation—665± feet

Description of strata	Thickness *Feet*	Depth *Feet*
Sand	12	12
Clay, blue	14	26
Shale	9	35
"Pyrite of iron"	2	37
Shale	3	40
"Conglomerate"	3	43
Shale	2	45
"Soapstone" shale	75	120
Shale, sandy	2	122
"Soapstone" shale	33	155
Shale	45	200
Limestone	190	390
Sandstone	30	420
Limestone, white	180	600
Sandstone (*St. Peter*)	150	750
Limestone, sandy	125	875
Sandstone	113	988
Limestone	134	1122
Sandstone	100	1222
Limestone	124	1346

GARDNER

The village has no water works. The private wells range in depth from 40 to 50 feet and most of them obtain water from sand and gravel beds in the till.

MAZON

The record of a deep boring on a farm near Mazon is given below. The amount and quality of water obtained from the St. Peter sandstone is not known. The curb elevation is approximately 600 feet.

Log[1] *of well sunk on the farm of Ed Walker 2 miles south, 1 mile west of Mazon, Grundy County, Illinois, in the SW. 1/4 sec. 28, T. 31 N., R. 7 E.*

(Geologic interpretations by G. H. Cady)

Description of strata	Thickness *Feet*	Depth *Feet*
Recent and Pleistocene series		
Soil	6	6
Clay, blue	160	166
Pennsylvanian system		
Shale ("soapstone"), slate, black, 4 feet	40	206
Sandstone, blue	18	224
Shale ("soapstone")	34	258
Ordovician system		
Maquoketa formation		
Shale ("soapstone")	46	304
Slate, black	12	316
Shale (hardpan)	16	332
Galena-Trenton formation		
Limestone, hard	216	548
Limestone, soft	60	608
Limestone, hard	12	620
St. Peter formation		
Sandstone, white	87	707

MINOOKA

The source of the public supply is a 620-foot well drilled in 1905, to the St. Peter sandstone. There is about 100 feet of 12-inch casing, and the bottom diameter is 6 inches. The water level at rest in 1915 was 70 feet below the surface, or at an altitude of about 550 feet; but the recession while pumping is not known. A yield of 90 gallons per minute has been obtained. The average daily consumption is 5,000 gallons.

A 2,100-foot flowing well drilled in 1886, had at that time a static head 46 feet above the surface, or at an altitude of 660 feet. At the time the well was drilled, the flow was over 100 gallons per minute at the surface, and the water flowed directly into the mains with sufficient pressure to supply the town. The present yield is about 50 gallons per minute at an elevation of 4.5 feet above the surface. The temperature of the water is 66.5°F. Because of the high mineral content and the corrosion of pipes and casing, the water was not satisfactory. The 620-foot well was drilled in 1905, and the water from the old well has not been used as a public supply since that date.

The mineral content of both waters is very high. The 2,100-foot well has a large amount of sodium chloride and also considerable

[1] Well drilled and record furnished by C. W. Johnson, Seneca, Ill.

calcium carbonate. The St. Peter water is not so hard, but the mineral content is high for a water from this formation in this locality. It may be that some of the water from the 2,100-foot well escapes into the St. Peter sandstone and thus affects the character of that obtained from the 620-foot well.

A driller's log, furnished by the J. P. Miller Artesian Well Company, Chicago, of an oil test drilled in 1902 for Jos. Junk in or near the village is as follows:

Driller's log of the oil test at Minooka

Description of strata	Thickness *Feet*	Depth *Feet*
Gravel, sand, clay	44	44
?	91	135
"Soapstone", shale	5	140
Limestone	300	440
Sandstone (*St. Peter*)	110	550
Shale, gray	108	658
Limestone	207	865
Shale and limestone	53	918
"Hard rock"	67	985
Limestone	75	1060
Shale, sandy, blue	102	1162

MORRIS

The city has three St. Peter wells that are about 700 feet deep. A new 720-foot well was completed in 1915, and the record of the strata, as determined from a study of the drillings, is given on the following pages. A driller's log of an old well drilled on the farm of Abe Hoge about four miles northeast of Morris is also given.

The chief source of the present supply is a 10-inch well that is 765 feet in depth. The amount of casing is not known, but it probably extends through the "Coal Measures," or to a depth of 140 feet. The water level at rest is 48 feet below the surface, or at an altitude of about 455 feet. The recession during pumping has not been determined. The average rate of pumping is about 160 gallons per minute, and the daily consumption is about 235,000 gallons. There is also an old, 650-foot well that is rarely used.

The recently drilled, 720-foot well is cased with 82 feet of 20-inch surface pipe and with 335 feet of 16-inch casing extending from the ground surface to the top of the St. Peter sandstone. This insures water from only the St. Peter sandstone. The cost of the well was $4,927. The pumping equipment has not been installed, so that there have been no determinations of the yield.

Other deep wells in the city are at the Gebhard Brewery, Coleman Hardware Company, and the Woelfel Tannery. These wells probably penetrate the St. Peter sandstone.

Analyses of the water from the 765-foot city well and from the Gebhard Brewery well are given. The waters are similar and have a very moderate amount of dissolved mineral matter. The water is used in the boilers at the brewery, but is first passed through a heater where a small amount of soft scale is deposited.

Log of an artesian well on the farm of Abe Hoge, NW. 1/4 NW. 1/4 sec 25, T. 34 N., R. 6 E.

(Well drilled in 1875)

Description of strata	Thickness Feet	Depth Feet
Quaternary system		
Pleistocene and Recent series		
Soil	5	5
Pennsylvanian system		
Shale and sandstone	70	75
Ordovician system		
Galena-Platteville		
Limestone	200	275
Shale	2	277
St. Peter sandstone		
Sandstone	200	477
"Cement" and shale	8	485
Sandstone	60	545
Prairie du Chien group		
Limestone, white	185	730
Sandstone, white	93	823
Limestone, white	326	1149
Cambrian (?) system		
Sandstone, red	166	1315
Limestone, gray	30	1345
Sandstone	317	1662
Limestone, gray	43	1705
Sandstone	163	1868

Log of city well No. 2, Morris, Ill.

Elevation—503± feet

Drilled in 1914-1915 by Cater Contracting Co., Chicago

Detailed log

(Samples studied by author)

Description of strata	Depth in feet *From*	*To*
Quaternary system		
Pleistocene and Recent		
Sand, yellow, clay, white chert and fragments of yellow, leached, dolomite pebbles	0	5
Pebbles of dolomite and igneous rock, sand, and chert	5	15
Pebbles, coarse gravel, and sand; pebbles are for the most part arenaceous dolomite or chert, with a few of the smaller ones composed of red granite or dark-colored igneous rock	15	30
Pebbles, sand, gravel, and chert	30	35
Sand, rather coarse and a few fragments of chalcedonic chert	35	50
Pennsylvanian system		
Shale, drab colored, micaceous. No samples between 55 and 67 feet	50	55
Coal, black, vitreous, cubical fracture. No samples between 69 and 83 feet	67	69
Shale, drab colored, micaceous; sample collected at depth of 83 feet	83	...
Shale, drab colored, micaceous; very similar to preceding, sample collected at depth of 100 feet	100	...
Shale, drab colored, micaceous; similar to the preceding; collected at 115 feet	115	...
Ordovician system		
Galena-Platteville limestone		
Limestone, shaly, micaceous, gray, might almost be called a soft, calcareous shale; some small crystals of pyrite; sample collected at 139 ft., thickness not given	139	...
Limestone, gray to light gray, dense; fragments effervesce with cold, dilute hydrochloric acid; a few small pieces of pyrite noted	139	160
Limestone, gray, dense; fragments of light and dark gray limestone, the lighter-colored material effervesces vigorously with cold, dilute acid, while the darker fragments do not effervesce as strongly unless allowed to stand for a few minutes; this dark gray material seems to be somewhat dolomitic	160	180

Log of well No. 2, Morris, Ill.—Concluded

	Depth in feet From	To
Limestone, gray to light gray, fine grained; good effervescence with cold, dilute acid	180	200
Limestone, gray to light gray, fine grained; some of the fragments are lithographic in character, while other darker colored pieces are somewhat dolomitic, not effervescing as easily with the cold acid	200	220
Limestone, like the preceding	220	240
Limestone, gray, fine grained; considerable action with cold, dilute acid; sample taken at depth of 275 feet	240	275
Limestone, dolomitic, light gray, fine grained, sample taken at depth of 300 ft	275	300
Limestone, somewhat dolomitic, fine grained	300	325
Limestone, slightly dolomitic, gray, fine grained	325	330
St. Peter sandstone		
Sandstone, colorless, rounded quartz sand ranging in size from a powder to grains .8 mm. in diameter, averaging about .4 to .5 millimeters; there are also present fragments of sandstone which have a dolomitic cement; these undoubtedly are from the contact between the sandstone and the overlying formation	330	335
Sandstone; colorless, rounded quartz sand, similar to the preceding in size; no fragments of sandstone with dolomitic cement	335	340
Sandstone, like the preceding; not stated from what depth sample was collected but probably at 500 ft.; some fragments of rusted iron particles broken from bit in drilling. This sandstone probably continues to 720 feet	335	500
Prairie du Chien group		
Dolomite , light gray, subcrystalline; scarcely any action with cold, dilute acid, but vigorous effervescence on heating; the material has been powdered extremely fine and only a few fragments were found showing the material's true character; a few small pieces of the red chert usually present at top of "Lower Magnesian" formation were found. Either this red cherty horizon was very thin at this locality or the sample was collected at a slightly lower horizon. Some rounded sand grains also noted; sample collected at depth of 720 ft. thickness not indicated	...	720

KANE COUNTY

Physiography

Kane County is in the northeastern part of the State and in the second tier of counties south of the Wisconsin boundary. It adjoins McHenry County on the south and is directly east of DeKalb County. The total area is 527 square miles.

The part of the county north of the latitude of Geneva is occupied by a composite system of moraines.[1] The southern half of the county, although it is covered by a mantle of drift, does not possess the rough, irregular topography of a terminal-moraine area. In the western part of the county, an elevated belt called the Marengo Ridge extends southward from McHenry County. The ridge continues to the vicinity of Elburn and has a width of 3 to 4 miles. The elevations of this area are seldom less than 100 feet and in places 150 feet above those of the more level tracts to the west and east. The topography of this ridge is characterized by small hills or knobs with rather steep slopes and by basins of irregular shapes, some of which have no outlet.

An irregular level belt 1 to 2 miles wide lies east of the Marengo ridge and at a lower elevation. To the east then follows the composite morainic area as far as Fox River. The topography as a whole is of the character of a terminal moraine, although in places it is gently undulating. There are also level tracts acres in extent completely surrounded by knolls 20 to 40 feet high. These areas have been drained by ditches.

The uplands along Fox River are in places 150 feet above the water, but although the slopes may be rather steep, there are few distinct bluffs in the northern part of the county. In the southeastern townships the rock outcrops along the river form bluffs.

The southern half of the county is slightly rolling and does not possess the knoll-and-basin type of topography characteristic of the area to the north.

The drainage of practically the entire county is effected by Fox River and its tributaries. This stream flows southward along the eastern border for the entire length of the county. Tributaries of Kishwaukee River and its South Branch which flow west and north drain the townships along the northwestern border. The drainage in the morainic area of the northern half of the county is so inadequate that it has been found necessary to resort to artificial drainage by tiling and ditching.

Geology

The northern half of the county is overlain by a heavy mantle of drift that is in places 200 feet deep. Beds composed almost entirely of sand and gravel occur in places but blue or bluish-drab clay is the most common constituent. Borings in the northwestern townships indicate

[1] Leverett, F., The Illinois glacial lobe: U. S. Geological Survey Monograph 38, p. 290, 1899.

that the drift is over 100 feet in thickness, and few of the farm wells enter rock.

Along Fox River valley in the part of the county south of the latitude of Geneva, the drift is generally less than 100 feet thick, although on knolls and ridges the depth is greater. In Sugar Grove Township the drift varies in thickness from 15 feet and less to over 75 feet. In Big Rock Township the drift is also thin and rock outcrops occur along Rock Creek.

The bed rock formation underlying the greater part of the county is the Niagaran limestone. It seems very probable however, that along the western border the Maquoketa shale underlies the drift. This is indicated by a well driller's log which reports shale underlying the drift in the N. ½ sec. 26, Big Rock Township; also 127 feet of shale is reported beneath 24 feet of bed rock limestone. The bed rock formation in the Sycamore and De Kalb wells, 4 and 8 miles, respectively, west of the county border, is the Galena-Platteville limestone, that underlies the Maquoketa.

The sequence of strata is indicated by numerous good logs given in the descriptions of the different localities. The general succession is similar to that in the counties to the east and north. The beds have a slight dip toward the east and south.

Underground Waters

SOURCES

The drift wells furnish sufficient water for farm uses, although the common practice is to continue these wells for a short distance into the limestone. Flowing shallow wells are not common, but a few are noted south of Aurora. In section 21, Big Rock Township, a flowing well on Mr. A. Zebby's farm is 96 feet deep in drift. Also in the northwestern part of the county a few flowing drift wells have been obtained in T. 41 N., R. 6 E.

Springs occur in many places along Fox River, as at Carpentersville, Dundee, and Aurora.

The larger towns in the county are all situated along Fox River and obtain their municipal supplies from "Potsdam" wells. Although the St. Peter sandstone is water bearing, most of the wells are continued to the deeper strata where it is always possible to obtain good supplies.

A number of "Potsdam" wells have been drilled by the cities in Fox River valley, and some lowering of the water table has resulted. This recession has not been great at Elgin, but farther south, at Aurora, it is noticeable. The recession at Elgin is reported to be only 4 or 5 feet

in the past ten years. There are no exact data for the wells at Aurora, but the head in 1899 was about 60 feet above the surface. The present water level in these wells could not be determined when at rest, but they do not flow, and the pumping level in 1914 was 53 feet below the surface. A well recently drilled in Aurora is 2,263 feet deep, and its head is about 3 feet above the surface, or at an altitude of 624 feet; this is considering that the Aurora city datum is 537 feet. This is the only flowing "Potsdam" well in the county.

CHEMICAL CHARACTER

The waters from all the horizons are somewhat mineralized. The predominant salts in the waters from the drift and underlying limestone are the carbonates of calcium and magnesium. The waters from these shallow depths do not usually contain the hard scale-forming magnesium sulphate in any great amounts, but, a spring water at Aurora contains a large amount of this salt.

The water from the St. Peter sandstone at Elgin contains a very noticeable amount of hydrogen sulphide. The sulphurous character of the water from this formation has been slightly noted in other parts of the country, but it is not so marked as that in the Elgin wells.

At St. Charles the water from the St. Peter sandstone is less mineralized than that from the shallower wells. This relation, however, may not hold for all parts of the county.

A large number of analyses of well waters in Aurora have been obtained. The deeper wells are as a rule cased only to bed rock, a condition that permits the entrance of upper-strata waters. The waters are only moderately mineralized and in many of the factories are used for boiler purposes.

There is danger of obtaining very highly mineralized waters from wells of great depth. In Aurora there is a notable increase in the amount of dissolved salts in waters from wells over 2,350± feet in depth. This same depth would not apply for the entire county, but as sufficient supplies can be obtained at less depths it is not advisable to drill deeper.

LOCAL SUPPLIES

AURORA

The water supply of Aurora is furnished by a series of "Potsdam" wells which range in depth from 1,388 to 2,263 feet. One group of five wells is at the water-works station located in the extreme northern part of the city on the east bank of Fox River. The maximum distance between any of the wells is only a few hundred feet. The depths

are all about 2,250 feet, except No. 1 which is only 1,388. The three oldest wells have been in operation for 18 or more years, but the other two have been drilled more recently. Well No. 5 was completed about 1910. The diameter of Well No. 5 is reported to be 16 inches at the surface and 8 inches at the bottom. It is probable that the older wells are considerably smaller. The wells are all pumped by means of air and the combined average daily pumpage is 2,400,000 gallons.

The rapid growth of the city and the heavy consumption during the summer demanded an increased supply. It was therefore decided to drill separate wells of large bore in different parts of the city, somewhat after the plan adopted at Rockford. The first of these isolated wells was drilled in 1915 at Talma Street, which is about two and one-half miles almost due south of the old pumping station. This well is 2,185 feet in depth; the surface pipe is 20 inches in diameter and the hole is finished at 15 inches. The only casing is from the surface to a depth of 350 feet.

The pumping equipment consists of a combination 4-stage, 17-inch, deep-well, turbine pump, and a 2-stage, vertical booster pump placed at the surface. The pumps are electrically driven. The cost of the finished well was a little over $25,000, which included $18,000 for the drilling and the remainder for the pumping equipment and pump house. A delivery of 450 gallons per minute was being obtained in July, 1915, with a recession of 160 feet in the water level. A much greater yield was expected, and with reason, since it is noted that the wells of smaller bore deliver nearly this amount. It is possible that some water may be lost through crevices in the limestone or in other porous formations.

The River Street well was completed in the summer of 1915 at a depth of 2,263 feet. The location is a little over a mile to the west and north of the one at Talma Street. The diameter of the surface pipe is 22 inches, and the hole is 15 inches at the bottom. Casing extends from the surface to a depth of 255 feet or through the Maquoketa shale. The total cost of drilling and piping was $20,280. This well had an estimated flow of 150 gallons per minute, at 2 feet above the surface, or a head of 87 feet above Aurora datum. This is equivalent to an approximate altitude of 624 feet. The water level at rest in the Talma Street well was 48 feet below the surface, but when it is considered that the elevation at River Street is 53 feet lower, it is seen that the water levels are essentially the same. The pumping equipment of the River Street well has not been installed at the present writing, so that the effects of pumping cannot be given. Another well of a similar size is being drilled which probably will be about 2,300 feet deep.

There has been a recession in the artesian water table in Aurora as in other localities of northeastern Illinois. The exact amount of this lowering is not known, but it has been over 80 feet since 1899. The static head in that year, as reported by Leverett was 60 feet above the surface at the water works. The present water level in these wells at rest is not exactly known, but it was 53 feet below the surface in one well in the fall of 1914 while the other wells were in operation.

Another deep well owned by the city is located in Phillips Park. The depth is 2,759 feet and it is therefore one of the deepest wells in Illinois. The driller's record of the strata penetrated is similar to the records of other wells in the city. A series of sandstones was struck at 1,847 feet and these continued to the full depth of the well; no specific descriptions of the sandstones were given. The water has a large content of dissolved mineral matter so that a slight salty taste is noticeable.

The few other deep wells in Aurora are at the Aurora Bleachery, Western Wheeled Scraper Company, and the Munroe Bindery. The depths are not over 1,420 feet, and the water is from the first "Potsdam" sandstone, the St. Peter, and any other water-bearing strata at shallower depths. The surface diameters are not over 12 inches and the bottom diameters are 8 or 6 inches, and perhaps less.

The well at the Western Wheeled Scraper Company was drilled in 1901 to obtain water from only the first "Potsdam" sandstone; 600 feet of 5-inch and the same amount of 3-inch piping, was continued from the surface to a depth of 1,200 feet and a rubber packer was placed at that depth. The analysis of this water is given and very probably represents the water from this horizon at this locality. That the rubber packer may be worn out and that leaks may have developed in the pipes does not seem probable, as an analysis made in 1901 is essentially the same as the one of 1915. This water is moderately mineralized and is similar to that obtained from other wells of like depth in the city. The water level in this well in 1901 was 30 feet below the surface and in the fall of 1914 it was 78 feet, the lowering amounting to 48 feet; the curb elevation is about 688 feet. This level is approximately 14 feet lower than that in the new city wells. These wells are much deeper, and it is therefore probable that the water obtained from the lower strata has a greater head.

As the well at the Scraper works is not large, the pumpage is only about 40 gallons per minute. The Munroe Bindery reports a yield of 225 gallons and the Aurora Bleachery a yield of 400 gallons per minute. This latter figure seems rather high.

The waters from all of the deep wells in Aurora are somewhat mineralized, and although the water from certain wells is used for boiler

purposes without treatment, some softening would be desirable. There is a great increase in the total mineral content of the water from depths greater than 2,250 feet. This is indicated in the River Street well and also the one at Phillips Park. In the latter case, the amount of dissolved mineral matter is so great that the water is not fit for use.

It was not possible to secure accurate temperatures as in most cases the water passed through pumps. The temperature of the water from the 1,280-foot well at the Bleachery was 57.2°F. This is pumped by air so that the temperature was taken as the water came from the well and before passing through a deep well pump as at the other wells. The water from the flowing well at River Street, which is 2,263 feet in depth, has a temperature of 63.5°F.

Some of the factories have shallow, rock wells a few hundred feet deep. The yields are 25 gallons or less per minute. The well at the W. B. Davis greenhouse in the northwest part of the city is 69 feet deep, of which 24 feet is surface material and the remainder limestone. The diameter at the surface is 12 inches and at the bottom, 10 inches. The water level at rest is about 18 feet below the surface, and 28 feet when delivering 125 gallons per minute. This is an unusually large yield for a well of this depth. The collecting area is probably the region of higher elevation to the west.

Log of Aurora City Well No. 8

Elevation—635± feet

(Drilled by G. S. Geiger, Chicago)

Generalized section[a]	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Soil, sand, etc.	18	18
Silurian system		
Niagaran limestone		
Limestone	142	160
Ordovician system		
Maquoketa shale		
Shale	170	330
Galena-Platteville limestone		
Dolomite and dolomitic limestone	280	610
St. Peter sandstone		
Sandstone	250	860
Prairie du Chien group		
Shale	50	910
Dolomite	30	940
Sandstone	40	980
Dolomite	110	1090

[a] The detailed log of this well compiled from study of samples is to be found in the Survey files if desired for reference.

BATAVIA

A knowledge of the strata at Batavia has been obtained through a study of the drillings from a 2,000-foot well which were collected by Mr. L. A. Parre, superintendent of the water works, and employees of the J. P. Miller Artesian Well Company. The general succession of strata is similar to that found in other parts of northeastern Illinois. There are, however, some variations in the thicknesses of the different formations. The St. Peter sandstone attains the unusual thickness of 309 feet, while the underlying Prairie du Chien limestone is thinner than common. The main water-bearing formations are the St. Peter sandstone and the "Potsdam" series.

The city has two deep wells that furnish the municipal supply. The location is on the banks of Fox River about 8 feet above the level of the water and the curb elevation is approximately 660 feet. The old well is 1,279 feet deep; the diameter at the surface is 10 inches and at the bottom 8 inches. This well is equipped with an air-lift pumping system and delivers 650 gallons per minute. This well flowed in 1895, but in September, 1914, the level was 35 feet below the surface after the pump had been stopped only long enough to measure. The 2,000-foot well was completed in 1915; the diameter at the surface is 12 inches and at the bottom 8 inches. The pumping equipment is an electrically-driven, 8-stage, turbine pump. The delivery is 1,140 gallons per minute with a recession of 34 feet in the water level. The static head at rest is 6 feet below the surface.

The analysis of the water from the new well indicates that it is only moderately mineralized. The greater amount of the dissolved solids is in the form of the bicarbonates of calcium and magnesium. The water is used in the boilers untreated, but it could be softened by the addition of a small amount of lime. It may be mentioned that the water obtained from the cherty horizon immediately below the St. Peter sandstone was reported to have been sulphurous. This chert and shale stratum has a tendency to cave and for that reason was cased off with 77 feet of liner which shut out all of the sulphurous water.

Log of City Well No. 2, Batavia, Ill., SE. 1/4 NW. 1/4 sec. 22, T. 39 N., R. 8 E.

Elevation 660± feet

Drilled 1914-1915, J. P. Miller Artesian Well Co., Chicago

Generalized section [a]

Description strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and recent		
No samples of surface sand and gravel, but probably about 6 feet	6	6
Silurian system		
Niagaran limestone		
Dolomite, gray to light gray, subcrystalline	134	140
Alexandrian series		
Dolomite, gray, soft	50	190
Ordovician system		
Maquoketa shale		
Shale, gray to dark gray	30	220
Galena-Platteville limestone		
Dolomite, gray to cream-colored, subcrystalline	300	520
St. Peter sandstone		
Sandstone, colorless, rather well rounded quartz grains	309	829
Prairie du Chien group		
Chert, gray to chocolate-colored	11	840
Dolomite, sandy	40	880
Sandstone	10	890
Dolomite, light gray to a light pinkish-gray, subcrystalline	120	1010
Sandstone, dolomitic and glauconiferous	50	1060
Dolomite, shaly, sandy, and glauconiferous	30	1090
Sandstone, dolomitic, glauconiferous	10	1100
Cambrian system		
Sandstone, colorless, rather well rounded, quartz sand, averaging about .5 mm. in diameter, not glauconiferous	190	1290
Dolomite, slightly sandy and glauconiferous	20	1310
Shale, siliceous and slightly dolomitic, some glauconite	130	1440
Sandstone, dolomitic, and sandy dolomite	90	1530
Shale, somewhat dolomitic	130	1660
Sandstone, ranging from fine to coarse in grain and from colorless to light yellow	240	1900
Sandstone, chocolate-colored, medium to coarse in grain	100	2000

[a] The detailed log of this well compiled from study of samples is to be found in the Survey files if desired for reference.

CARPENTERSVILLE

The village is located in the Fox River valley along the eastern border of the morainic belt. This high land to the west forms a good collecting reservoir so that at the lower elvations along the base, good wells can be obtained at shallow depths. The conditions are such as to give rise to a number of flowing wells.

The water supply for the village is furnished by a dug well 17 feet in depth and 19 feet in diameter located on low land east of Fox River. The material encountered in drilling was coarse gravel and "stone" except for 5 feet of surface soil and clay.

The water level is kept down to within 6 feet of the surface by means of an overflow to the Fox River, an eighth of a mile distant. It has been possible to lower the water level to within 4 feet of the bottom when pumping at the rate of 250 gallons per minute. No further lowering could be obtained at this pumping rate. Droughts do not appear to have any noticeable effect upon the water level.

ELBURN

A record has been obtained from the J. P. Miller Artesian Well Company of a well drilled in 1899 for the Illinois Condensing Company.

Log of well at Elburn

Elevation—848± feet

Description of strata	Thickness *Feet*	Depth *Feet*
Clay, sand, and gravel	154	154
"Rock", probably limestone	24	178
Shale	127	305
Limestone	258	563
Marl, red	2	565
Limestone	49	614
Sandstone (*St. Peter*)	66	680
Shale, white	15	695
Limestone, sandy	120	815
Limestone, and white shale	55	870
Sandstone	50	920
Marl, red	40	960
Limestone	145	1105
Sandstone, and sandy shale	270	1375

The water level at completion was 105 feet below the surface; the present static head is not known.

ELGIN

The geological succession at Elgin is indicated by the accompanying

log, compiled by Professor Savage from the driller's log and from a study of a few samples of the drillings. The main water-bearing formations are the St. Peter sandstone and the "Potsdam" group. The different strata lie at shallower depths in the vicinity of Elgin than in the territory to the east and west, because the elevations in Elgin and also at other points in the Fox River valley, are from 100 to 200 feet less than on the bordering uplands.

Log of Elgin city well

Elevation—738± feet

(Geologic interpretation by T. E. Savage)

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Clay, sand, and gravel; yellowish gray	38	38
Silurian system		
Alexandrian limestone		
Dolomite and limestone	27	65
Ordovician system		
Maquoketa shale		
Shale	50	115
Galena-Platteville limestone		
Dolomite, gray to dark gray; crystalline	70	185
Dolomite, like the preceding	140	325
Dolomite, gray to brown; subcrystalline	75	400
Dolomite, like the preceding	85	485
Dolomite, like the preceding	75	560
St. Peter sandstone		
Sandstone; clean rounded grains	80	640
Sandstone, like the preceding	62	702
Prairie du Chien group		
Dolomite, light gray; subcrystalline	48	750
Dolomite, like the preceding	130	880
Dolomite, gray to brown, some sand	20	900
Shale, slightly sandy, pink	115	1015
Shale, calcareous, bluish gray to gray	35	1050
Cambrian system		
"Potsdam" group		
Sandstone; rather large, clean, rounded grains	250	1300
Shale, calcareous, light pink	50	1350
Dolomite, light gray	74	1424
Sandstone; rounded grains	156	1580
Shale, slightly calcareous, gray to bluish gray	55	1635
Sandstone; rounded grains	5	1640
Sandstone, light pink; rather fine grains	145	1785
Sandstone, like the preceding, but larger grains	195	1980
Sandstone, pink; moderate-sized grains	25	2005

The municipal water supply is furnished by four deep wells, three of which are about 1,350 feet deep, the other is 2,005 feet. The deepest well was drilled in 1901 and was tested to determine the yield at different horizons. After drilling to the full depth of 2,005 feet a pumping test was made in which the yield and amount of lowering was noted. A plug was then placed at 1,400 feet and another test made. The results as to yield and lowering did not seem to differ essentially from those obtained before plugging. Therefore the other wells were drilled only to a depth of approximately 1,350 feet.

The city wells are only about 50 feet from Fox River, and approximately 150 feet apart. The pumping is accomplished by a shaft and tunnel system. In the interior of the pumping station a circular shaft, 120 feet in depth and 9 feet in diameter is sunk to the Galena-Platteville limestone. Two circular tunnels 9 feet in diameter dug in the Maquoketa shale lead off from the bottom of the shaft. One tunnel contains the pipe that taps the 2,005-foot well; the other tunnel is connected to the three remaining wells. The wells are 16 inches in diameter at the surface and cased to a depth of 140 feet or about 20 feet below the tunnels; the diameter at the bottom is 8 inches.

At the time the wells were drilled a flow of sulphurous water was obtained from either the St. Peter sandstone or the underlying cherty horizon. The flow ceased as the depth increased. The present water, however, is characterized by a noticeable amount of hydrogen sulphide.

The static head at rest in 1914 was reported to be about 14 feet below the surface; the curb elevation is 742 feet. The water level recedes to at least 115 feet on heavy pumpage. The recovery is very rapid so that in a few hours after the pumping has ceased, the water has returned to its original level. The static head in 1903 at the time the wells were drilled, was 11 feet below the surface.

Some other deep wells in the city are those of the National Brewery, Elgin Watch Works, and Borden's Condensed Milk Co. The two wells at the Elgin Watch Works are 500 and 2,000± feet in depth. It may be that the 500-foot well penetrates the St. Peter sandstone, as it is reported to have flowed until the city wells were drilled. At present the water is about 30 feet below the surface. The temperature of the water was 54.7°F. The 2,000-foot well is very old and may be somewhat filled up. The temperature was 61.3°F.

The analyses of the waters from the wells at the Elgin Watch Works are given. The water from the 500-foot one is the softer, al-

though its total mineral content is greater than that of the deeper well water. The water from the shallower well is used in the boilers, but with daily alternation with that from Fox River. Although no scale is formed some sludge is deposited.

GENEVA

The city water supply is obtained from a well about 850 feet deep in the St. Peter sandstone. The location is near Fox River and at a low elevation. The diameter at the surface is 10 inches and at the bottom 8 inches.

The well would flow about 50 gallons per minute, in 1911, but this was not sufficient so that pumping was necessary. The static head at present is within a few feet of the surface. Pumping is effected by means of an air-lift system at the rate of about 300 gallons per minute. The average daily consumption is 350,000 gallons. The water contains scarcely a trace of hydrogen sulphide.

Formerly there was a 2,500-foot well at the court house, and another one 2,000 feet in depth at the Pope Glucose Company; these have been abandoned for many years.

MAPLE PARK

The village water supply is obtained from a well 250 feet in depth. The entire thickness is reported to be in drift. The maximum yield has not been determined, but the pump delivers 40 gallons per minute. The analysis indicates a water with only a moderate amount of dissolved mineral matter. If used untreated in boilers, a small amount of soft scale would be formed.

MONTGOMERY

The village of Montgomery adjoins Aurora on the south. The Montgomery Magnesia Spring Company has a flowing well, although the static head, which is about 4 feet above the surface, is shut in. The location is on the banks of Fox River, and the curb elevation is about 8 feet above the water level in the stream. The depth is probably about 115 feet. The analysis of the water shows that the principal constituent is sodium carbonate. The water is bottled and sold in the vicinity.

There are a few other flowing shallow rock wells in this vicinity, as at Riverview Park about a mile south of Montgomery and at the Chicago, Burlington, and Quincy Railroad sheep barns, about half a mile west of Montgomery.

MOOSEHEART

The school at Mooseheart, established by the Order of Moose, is located about a mile south of Batavia. The water supply is furnished by a 1,840-foot well, and another deep well is being drille. The formations are similar to those at Batavia. The St. Peter sandstone at a depth of 585 feet has a thickness of 248 feet, whereas at Batavia it is 309 feet. The curb elevation at Mooseheart is 709 feet. The static head at rest in 1914 was 28 feet below the surface; the effects of pumping were not known.

The water contains a moderate amount of dissolved mineral matter, the greater part of which is in the form of the bicarbonates of calcium and magnesium.

ST. CHARLES

The city water supply is furnished by two wells, one of which is 350 feet and the other 850 feet deep. The shallow well is located at the water works on the banks of Fox River; the yield is 120 gallons per minute, and the temperature of the water is 51.5°F. The water is obtained from crevices in the Niagaran limestone. The 850-foot well is located at a separate pump house half a mile or more from the waterworks station. This deeper well penetrates the St. Peter sandstone; the ground elevation is 748 feet, which is about 53 feet greater than that at the 350-foot well. The St. Peter well is pumped at the rate of 150 gallons per minute; the surface diameter is 10 inches, and it is probably 8 inches at the bottom. The static head in the 850-foot well at the time it was drilled in 1913 was 50 feet below the surface. The level in 1914 while pumping about 150 gallons per minute was 89 feet. The pumping was stopped for 25 minutes and the water rose to within 55 feet of the surface. The analyses of the waters from the two wells are given. The St. Peter water is not so hard a water as that from the Niagaran limestone or 350-foot well. However, the St. Peter water has a sulphur taste and odor which is absent in the water from the shallow well.

The St. Charles School for Boys 2 miles west of town, has three wells. Two of the wells are 1,108 and 1,320 feet in depth, respectively; the other is a shallow well of an unknown depth. The deeper wells obtain their water from the St. Peter sandstone, and the 1,320-foot well may possibly penetrate the first sandstone of the "Potsdam" group. The surface elevation at the 1,320-foot well is 788± feet, and the water level was 93.5 feet below the surface one-half hour after cessation of pumping. This is essentially the same level as noted in the city well penetrating the St. Peter when the differences in ground elevation are taken into consideration. The analyses of the waters from the 1,108 and the

1,320-foot wells are very similar to that of the 850-foot one at St. Charles.

VIRGIL

The Borden Condensed Milk Company has a "Potsdam" well 1,580 feet deep. The yield is at least 120 gallons per minute. The static head is not known.

KANKAKEE COUNTY

Physiography

Kankakee County is situated along the eastern border of the State directly south of Will County. The total area is 668 square miles.

The topography of the county, as a whole is that of a monotonous plain. The maximum relief of probably not much more than 150 feet has been brought about by Kankakee River. The part of the county west of Iroquois and Kankakee rivers presents a very level appearance; the slight depressions are in many places characterized by marsh conditions. The area north of the Kankakee has somewhat more relief, but has nevertheless a rather level surface broken only by creeks and occasional sloughs. Likewise, in the southeastern townships there are extensive marsh areas.

The major drainage is effected by Kankakee River and its tributaries. This stream flows across the central portion of the county in a westward direction, leaving the county in the northwestern part and finally joining with the Desplaines to form the Illinois. The headwaters of minor tributaries of the Illinois drain the extreme western tier of townships. A large portion of the county is inadequately drained because of the flat topography; marshes and swamps exist in many localities.

Geology

The greater part of the county has a drift covering which ranges in thickness from a few to a hundred or more feet. Along the Kankakee and its immediate tributaries the drift is so thin that bed rock outcrops in a number of places. In the extreme northeastern townships, near the border of the Valparaiso morainic area, thicknesses of 50 to 100 feet have been recorded. The depth to bed rock at St. George and at Manteno ranges from 10 to 20 feet. Much of the northern part of the county west from Manteno has only a thin coating of surface deposits; the rock outcrops some of the streams. In the extreme southwestern corner, along the border of the Marseilles moraine, the drift thickness in six wells ranged from 100 to 162 feet.[1]

[1] Leverett, Frank, The Illinois Glacial Lobe: U. S. Geol. Survey Monograph 38, p. 654, 1899.

Rock is encountered in the vicinity of Irwin and Hersher at depths of 40 to 60 feet. The drift is generally thin from Union Hill east to the Kankakee; but westward from this village to the county line the thicknesses range from 50 to 100 feet. At St. Anne in the southeastern part of the county, bed rock is found at about 60 feet.

The bed rock formation underlying all of the county, outside of a narrow strip along the western border, is the Niagaran limestone. This formation outcrops in places along the Kankakee and its major tributaries. The strata rise toward the west so that formations underlying the Niagaran are brought to the surface.

Professor Savage[1] has described a limestone at Essex which is "intermediate in age between the' Niagran' and Maquoketa shale. He named this formation the Essex limestone and assigned it to the middle part of his Alexandrian series. The Maquoketa shale is the next formation of any considerable extent which outcrops to the west of the Niagaran limestone region and forms a north-south strip a few miles in width. The outcrops of the Alexandrian series occur between the Niagaran and Maquoketa areas, but because of their thinness they have not been separately mapped as yet. The large area of Pennsylvania coal-bearing strata to the west, extends into this county long its western border.

The strata have an eastward dip of about 17 feet to the mile, as calculated from the outcrop of the Maquoketa at Essex and its depth at Kankakee. There seems to be a very slight dip toward the north; the St. Peter sandstone in South Chicago is at an altitude 80 feet lower than at Kankakee, a difference that would give a dip of 2 feet to the mile.

The only accurate record of deep drilling in this county is from Kankakee. The wells at the State Hospital for the Insane are over 1,800 feet in depth, but no log was kept of the strata below the St. Peter sandstone. The geological succession, as determined from a study of the drillings by Professor Udden[2], is similar to that at Joliet and Chicago. The St. Peter sandstone was struck in the Kankakee well at a depth of 890 feet; the curb elevation is approximately 615 feet. Toward the west part of the county the depths to this waer-bearing formation will gradually decrease so that it will probably be found at 650 to 750 feet below the surface. The depth to this formation increases eastward from Kankakee and probably in the townships along the eastern border it is over 1,150 feet below the surface.

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[1] Savage, T. E., Stratigraphy and paleontology of the Alexandrian series in Illinois and Missouri: Ill. State Geol. Survey Bull. 23, 1913.

[2] Udden, J. A., Some deep borings in Illinois: Ill. State Geol. Survey Bull. 24, 1914.

The first sandstone of the "Potsdam" group, which is the chief water-bearing horizon at Joliet and Chicago, was encountered in the Kankakee wells, but its depth was not recorded. This formation at Joliet was struck about 600 feet below the top of the St. Peter sandstone, and this figure can be used for calculations in Kankakee County.

The Pennsylvanian strata in the western tier of townships is commonly a series of shales, sandy shales, and thin sandstones, and a few thin coal beds. In many places the waters from these beds are sulphurous or salty.

Underground Waters

SOURCES

The ground waters, which have been extensively utilized, are obtained from the Niagaran limestone or the drift deposits. The only deep wells in the county are at the State Hospital for the Insane at Kankakee. The Valparaiso morainic system in Will County forms a collecting reservoir for the rainfall creating a condition favorable for ground waters in that part of Kankakee County north of the Kankakee; supplementary favoring factors are the sandy soil, flat topography, and southward slope of the land surface. The slight relief and somewhat sandy soil prevent excessive run-off in other parts of the county as well. The only information regarding the static head of the artesian water from the deeper strata has been obtained at Kankakee. This will be discussed in the description of the water resources at that locality.

CHEMICAL CHARACTER

The waters from the Niagaran limestone are rather hard as indicated in the analyses. The chief salts are the carbonates of calcium and magnesium with a considerable amount of magnesium sulphate. In the western tier of townships many of the wells penetrate the Pennsylvanian strata underlying the drift and produce sulphurous or even salty water; in this connection the conditions at Reddick should be noted.

Wells of a depth much greater than 1,850 feet may be expected to furnish a highly mineralized water. This inference is drawn from the deep well at Kankakee, and it is believed that similar conditions exist in other parts of the county. However, where the deep wells receive large additions of waters from the upper strata, the final product from the well will be considerably modified.

LOCAL SUPPLIES

KANKAKEE

The source of the municipal water supply is Kankakee River, but the water is treated before usage. There are, however, a number of rock wells drilled in the city in addition to two at the Hospital for the Insane which penetrate the "Potsdam" group.

The Niagaran limestone wells are represented by the one at the Radeke Brewery and those at the Kankakee Pure Milk Company. The well at the Radeke Brewery is 225 feet in depth and 8 inches in diameter at the surface. The location is within 75 feet of the Kankakee, about 7 feet above the water level in the stream. The yield is at least 80 gallons per minute with the working barrel of the pump at a depth of 65 feet; the water level is not known. The analysis indicates a hard water, but it is used in beer making after preliminary heating which precipitates some of the dissolved mineral matter.

The Kankakee Pure Milk Company has two Niagaran limestone wells, one 112 feet and the other 205 feet in depth. The latter is cased with 10-inch pipe to a depth of 30 feet or 27 feet below the bed-rock surface. The yield is from 75 to 100 gallons per minute with the working barrel at a depth of 60 feet; no diminution of the water supply has ever been noted. The water level is about 17 feet below the ground surface, but the effects of pumping are not known. Although the 112-foot well is of a much smaller bore it delivers about 25 gallons per minute. The analysis indicates a hard water with a rather large amount of dissolved mineral matter. The water is used for boiler purposes after softening.

The State Hospital for the Insane, situated immediately south of Kankakee and on the south side of the river, owns two interesting wells, drilled in 1908-09. They are located approximately 275 feet apart in a north-south direction near Kankakee River, at an elevation of about 10 feet above the water in the stream. The drillings from one of the wells down to a depth of 1,090 feet or through the St. Peter sandstone were studied by Prof. J. A. Udden.[1] This record is given on the accompanying pages. The strata below the St. Peter were not recorded, but they are very probably similar to those at Joliet, although some variations in the thicknesses may occur.

Well No. 1, or the north well, was originally drilled through the St. Peter sandstone, and a pumping test gave a yield of about 200 gallons per minute. In order to preclude all possibility of any water from the drift or upper part of the Niagaran limestone entering the well, about 100 feet of 15-inch surface pipe was carefully sealed at the bottom with concrete. A pumping test was again made after this casing had been placed and sealed off; but only a small amount of water was obtained, and a great lowering of the water level followed, indicating a strong flow of Niagaran limestone water into the well at the time the first test was made. In an attempt to obtain a greater yield, the drilling was continued

[1] Udden, J. A., Some deep borings in Illinois: Ill. State Geol. Survey Bull. 24, p. 50, 1914.

to a depth of 1812 feet and the well was finished 5 inches in diameter at the bottom. At the present time about 250 gallons per minute can be pumped, but the water has a very high mineral content.

The second well was drilled in 1909 to a depth of 1,847 feet. The 15-inch surface pipe is about 75 feet long; the hole is about 5 inches in diameter at the bottom. In this well the surface pipe was not sealed off as in the previous one, and there is every reason to believe that large additions of water are obtained from the Niagaran limestone. Analyses of the two waters show that the one from the 1,812-foot well in which the surface pipe was sealed off, has much the higher mineral content. The temperature of this water is 61.5°F. and the static head is 126 feet below the surface, or an approximate altitude of 489 feet. The water from the 1,847 foot well is similar to that from the Niagaran limestone, except that the mineral content is somewhat greater, due chiefly to an increased amount of sodium chloride. The temperature is 56.2°F., and the water level is 51 feet below the surface, or at an approximate altitude of 564 feet. The yield is about 250 gallons per minute.

The water from the 1812-foot well, in which the surface pipe was sealed off with concrete, has the following "Potsdam" characteristics: high mineral content, chiefly sodium chloride, or salt; a higher temperature than waters from the shallower horizons; and a low water level. The water from the 1,847-foot well, in which the surface pipe was not sealed off, is similar in many ways to that from the Niagaran limestone; the temperatures, the analyses and the water levels are alike. Although some of this water is probably from the "Potsdam" group, by far the greater amount is from the Niagaran limestone.

Prof. Udden's summary of his interpretation of samples from one of these wells is as follows:

Log of well at the Hospital for the Insane, Kankakee

Drilled in 1908

Generalized section[1]

Description of strata	Thickness *Feet*
(Niagaran limestone). Dolomitic limestone, yellow, white, and gray..	300
Cincinnatian shale	105
Galena-Trenton (upper part). Dolomitic limestone of mostly coarse texture and light color	355
Galena-Trenton (lower part). Dolomitic limestone of prevailing darker shale and finer texture	120
Dolomitic limestone, partly pure and partly containing embedded sand, with some green shale probably in separate seams. Beds of transition	15
(St. Peter sandstone). White, well worn quartz sand	190

[1] Udden, J. A., Some deep borings in Illinois: Ill. State Geol. Survey Bull. 24, p. 50, 1914.

MANTENO

The drift in the vicinity of Manteno is thin, so that the Niagaran limestone lies within 15 to 20 feet of the surface. The dug wells draw their supply from the drift overlying the bed rock.

The source of the municipal water supply is three wells that penetrate the Niagaran limestone. The largest well is 15 feet in diameter and 60 feet in depth. It is lined with concrete to a depth of 20 feet or 3 feet below the surface of the bed rock. At the bottom there is a tunnel connection with No. 3 well, situated 15 feet to the west. The depth of No. 3 is 426 feet; there is 17 feet of 10-inch surface pipe and the bottom diameter is 6 inches. The normal water level is 40 feet below the surface. The rate of inflow into these two wells is about 225 gallons per minute, but the large well can be emptied in approximately two hours when pumping at the rate of 450 gallons per minute.

There is also a 310-foot well located 60 feet west from No. 3; the diameter at the surface is 10 inches and at the bottom, 8 inches. An abandoned well 88 feet deep and 6 inches surface diameter is located about 10 feet south from the 310-foot one.

The water is hard and would form considerable tenacious scale if used in boilers without softening. The analysis is given.

MOMENCE

Most of the private wells are from 12 to 40 feet in depth, although rarely a deeper one is drilled. The water source is either a sand and gravel stratum overlying the Niagaran limestone or the bed rock itself.

The city supply is furnished by four wells located near Kankakee River; the diameters are 8 inches, and the Niagaran limestone is penetrated, but the depths are not known. The water level is within 12 to 20 feet of the surface. Two of the wells are close to the river and the water levels in the streams and wells are practically the same although there is no direct connection.

The average daily pumpage is about 320,000 gallons which is accomplished in approximately 16 hours of operation. There is no analysis of the water but it is hard and forms scale when used untreated in boilers.

REDDICK

The village has no municipal supply, but some data in regard to the ground waters has been obtained. The drift is from 60 to 75 feet thick and is underlain by strata of the Pennsylvanian system. This bed rock in many places contains sulphurous water and in many instances large amounts of salt.

The well at the town hall is probably 268 feet deep, the casing is 6 inch, but the length is not known. The material penetrated below the

drift was the Pennsylvanian to a depth of about 184 feet, and the remainder was limestone. The water obtained is too salty for drinking purposes; the analysis is given. A 4-inch drift well at the school house is 66 feet deep and yields a water of fair quality that is used for drinking.

If it is not possible in this vicinity to develop satisfactory supplies from the drift, the St. Peter or deeper horizons should be tried; the upper strata to the base of the lowest coal bed at least and preferably much deeper, should be cased off. The St. Peter sandstone will probably be found at from 700 to 750 feet and the first "Potsdam" sandstone about 600 feet deeper. The quality of the waters at these deeper horizons will very probably be better than those obtained within a few hundred feet of the surface.

KENDALL COUNTY

Physiography

Kendall County is located in the northeastern part of the State, south of Kane County and west of the northern portion of Will County. The total area is 324 square miles.

The Marseilles moraine[1] enters the county in the northeast corner, follows the west border for four or five miles and then swings abruptly to the west, crossing the county in a southwestward direction. Its western border is from less than a mile to not over 4 miles south of Fox River. Its average width is 2 or 3 miles. The elevations along this morainic belt are from 100 to 125 feet higher than those of the lower lands to the northwest. The ground moraine south of the Marseilles terminal moraine averages about 75 feet less in elevation. The surface of the terminal moraine is characterized by knolls, 24 to 40 feet in height covering an area of a few acres, and separated by saucerlike, irregular-shaped depressions generally poorly drained. Another elevated strip along the eastern border of the county called the Minooka Ridge[2] is scarcely 2 miles wide and has terminal-moraine topography.

Fox River and its tributaries have accentuated the relief somewhat in the northwestern townships. The elevations along the river are about 100 feet below those on the uplands a few miles distant. The topography of the remainder of the county outside the morainic areas and Fox River Valley is flat. The relief is very slight, and the slopes are gentle.

The drainage of the northern and northwestern parts of the county is effected to the southwest by Fox River and its tributaries. The re-

[1] Leverett, Frank, The Illinois glacial lobe: U. S. Geol. Survey Monograph 38, p. 309, 1899.

[2] Leverett, Frank, Idem, p. 319, 1899.

mainder of the county drains southeastward to Illinois River through Aux Sable Creek and minor streams.

Geology

The greater part of the county is covered by a mantle of drift, which probably averages 100 feet in thickness and is composed mainly of blue till (unstratified drift) which is characterized by a large amount of clay and only a moderate amount of coarse rock material. The drift is thin along the south-central border between the Marseilles moraine and the Minooka Ridge and is thickest along the Marseilles moraine where depths of 200 feet have occasionally been reported. Wells of 125 to 150 feet in which the bed rock has not been encountered are not unusual.

There are few rock outcrops except along Fox River. However, at least five different formations underlie the drift in the different parts of the county. The oldest known formation to be exposed is the St. Peter sandstone, which is found along the river at Millington.

The strata have a dip to the east that amounts to at least 23 feet per mile between Millington and Joliet. This dip causes the older formations to successively disappear under the next younger. Therefore, beginning with the St. Peter sandstone at Millington and going eastward the following strata are the bed-rock formations in order: Galena-Platteville limestone, Maquoketa shale, Alexandrian limestone and the Niagaran limestone. Strata of Pennsylvanian age occupy a few square miles of territory in the extreme southwestern corner of the county.

Underground Waters

SOURCES

Although the drift is of a considerable thickness over the great part of the county, the shallow wells do not produce large supplies because much of the drift is clay. Along Fox River the shallow wells penetrate gravel deposits above the bed rock and obtain quantities sufficient for domestic purposes.

Few wells over 1,000 feet deep have been drilled in the county, so that little is known regarding the waters from the deeper strata. In the vicinity of Millington, where the St. Peter sandstone is near the surface, a number of farm wells draw water from this formation. Flowing wells are obtained occasionally from the St. Peter sandstone in localities of low elevation.

LOCAL SUPPLIES

OSWEGO

The village supply is furnished by a dug well 22 feet deep and 14 feet in diameter. The material penetrated is drift except for the lower 4 feet

which is in Niagaran limestone. The water level is about 10 feet below the surface, and the approximate daily pumpage is 18,000 gallons. The analysis indicates a fairly hard water; scale would form if it were used for boiler purposes without treatment.

PLANO

The water supply is furnished by a dug well located at the Steward Mill in the east part of the village. The well is 10 feet in diameter and 14 feet in depth; it is located about 50 feet from Big Rock Creek. The lining of the well is concrete, so that all the water enters from the bottom. The mill furnishes the power for the pumping of 120,000 gallons per day.

The only record of a deep well in the county is from one on Fox River bottoms, 2½ miles south and a little east of Plano. The drillings were studied by J. A. Udden and his descriptions are given below.[1]

Log of well near Plano, Illinois
Generalized section

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Clay, sand, and gravel	40?	40?
Ordovician system		
Galena-Platteville limestone		
Limestone, dolomitic	550	590
St. Peter sandstone		
Sandstone	135	725
Prairie du Chien group		
Limestone, dolomitic with occasional thin beds of sandstone	385	1110

YORKVILLE

The Marseilles moraine, bordering the town on the southeast, has a number of springs along its base. Likewise, shallow wells less than 50 feet deep furnish supplies sufficient for domestic purposes. The source of the village water supply is a number of springs in the Marseilles moraine about a mile and a half east of town. The water flows from the springs into a collecting basin from which it is pumped to a reservoir at a higher elevation. It then flows by gravity to the village.

LAKE COUNTY

Physiography

Lake County is situated in the extreme northeastern corner of the

[1] Udden, J. A., Some deep borings in Illinois: Ill. Geol. Survey Bull. 24, p. 45, 1914.

State. Lake Michigan forms its eastern and the Wisconsin line its northern boundary. The total area is 455 square miles.

The west half of the county is occupied by the Valparaiso morainic system and is therefore characterized by a hummocky relief or knoll-and-basin topography. The hills range from 10 to 50 feet above the general surface, although a few of the larger ones are 100 feet above the lower areas. Shallow lakes, which are rarely over 50 feet in depth, are scattered among the knolls, and marshes exist in many of the depressions. The greatest altitudes are in the southwest part near Lake Zurich where elevations of nearly 900 feet, or over 300 feet above Lake Michigan have been recorded.

The topography of the eastern half is undulating and not so rough as that to the west. No distinct bluff is developed along Lake Michigan from the northern border south to Zion City. From this point southward, a bluff gradually develops which at Waukegan is about 40 feet in height. Its distance from the lake lessens toward the south; two or three miles north of Waukegan there is over a mile of lake flats whereas, a few miles south of that city the lake waters are at the base of the cliff. The height of the bluff from North Chicago to Lake Forest averages about 70 feet.

The entire county is characterized by inadequate drainage. In the northwest part numerous shallow lakes range in size from a few acres to several square miles. Many of the depressions are not well drained, so that marshes prevail in many areas. The western townships drain westward by small, winding streams that finally join to form Fox River which flows southward. The eastern half of the county drains southward through Desplaines River and the north branch of Chicago River which here are little larger than creeks.

Geology

The mantle of drift covering the entire county has probably an average thickness of more than 200 feet and is composed of stony blue clay with irregular beds of sand and gravel. In the lake region of the northwestern townships much sand is reported in the drift.

In many of the wells the rock surface is lower than the water level in Lake Michigan. Leverett believes that the rock surface will scarcely average as high as that of the lake.[1]

The depth to bed rock around the station at Zion City is about 115 feet, but about two miles to the west along the ridge, the drift is 185 to 190 feet thick. Along the lake bluff south from Waukegan it is 175 to over 200 feet to bed rock. At Grays Lake rock was struck at 230 feet and in the vicinity of Libertyville at about 200 feet. The greatest

[1] Leverett, F., The Illinois Glacial Lobe: U. S. Geol. Survey Monograph 38, p. 579, 1899.

thicknesses of drift are recorded from the southwestern townships; at Lake Zurich a 297-foot well did not strike rock, and at Barrington, just south of the county line, it is about 250 feet to rock.

The bed-rock formation underlying the entire county is probably the Niagaran limestone. The underlying strata are indicated by the detailed records from Lake Forest and Grays Lake. The formations below the St. Peter are more sandy than in the areas further south, as at Joliet. The strata have a slight eastward dip, probably not over 10 or 12 feet to the mile, and the southward dip is less, as very little difference was noted between the altitude of the St. Peter sandstone at Zion City and Ravinia.

Underground Waters

SOURCES

At the present time the greater number of towns along Lake Michigan obtain their municipal supply from the lake, but formerly the source was deep wells. The deeper wells draw their supplies from the St. Peter, Prairie du Chien, and "Potsdam" formations. The strata below the St. Peter in this area have a greater development of sandstones than in the regions farther south which creates favorable conditions for underground waters.

The chief source of ground water in this county is either from sandy beds in the drift or the underlying Niagaran limestone. Only a few of the larger towns have drilled deep wells.

The static head of the waters from the deeper strata is sufficient to produce flowing wells in the extreme northeast corner of the county. A flow may also be obtained at the low elevations that prevail along the base of the lake bluff. The recession of the static head has not been so great as in Cook County to the south. A 1,568-foot well at Zion City in 1901 had a static head of 30 feet above the ground surface, or an approximately 680-foot elevation. This well flows at present at a curb elevation of 648 feet, but the head is not much above the curb. The 1,900-foot well at Lake Bluff had a head of 45 feet above the surface thirty years ago. The water level at present is 45 feet below the ground, or at an altitude of approximately 635 feet. The water level in the recently completed 1920-foot well at the country estate of Ogden Armour, two miles west of Lake Forest, was 42 feet below the surface, or at an altitude of 648 feet.

CHEMICAL CHARACTER

The mineral content of the waters from the drift and Niagaran limestone have shown considerable variation. The bicarbonates of cal-

cium and magnesium usually dominate, but varying amounts of the sulphates of magnesium, calcium, and sodium may be present. It is desirable, and in many cases necessary, to soften the water before it is used in boilers.

Many of the Niagaran limestone wells yield a water that contains some hydrogen sulphide. Generally the amount is not great, but in some instances the water is objectionable for drinking purposes to people not accustomed to it. A few deeper drift wells have yielded a somewhat sulphurous water.

It is impossible to draw any detailed conclusions regarding the waters from the deeper strata, because the wells are cased only to bed rock and varying amounts of water from the upper strata enter the wells. The essential difference between the deeper waters and those from the Niagaran limestone is in the absence of hydrogen sulphide in the former, and in its presence in the latter.

The 1,991-foot well belonging to E. S. Moore at Lake Forest is cased to a depth of 1,660 feet. The water delivered has a total mineral content of 29.899 grains per gallon, of which 23.157 grains were incrusting solids. From the analysis given it is seen that some of the Niagaran limestone waters have as low a mineral content.

LOCAL SUPPLIES

GENERAL STATEMENT

Nearly all the towns along the lake shore draw their municipal water supplies from Lake Michigan; Many deep wells have been abandoned in favor of the softer lake water. The recession of the water table has also been instrumental in bringing about a change in the source of the municipal supplies.

GRAYS LAKE

The Wisconsin Condensed Milk Company has recently completed a 1,040-foot well. The drillings were collected at intervals of 10 feet, and the record obtained from a study of these samples follows:

Log of well owned by Wisconsin Condensed Milk Co., Grays Lake, Lake County

Elevation—800± feet

Drilled in 1916, by S. B. Geiger, Chicago

Generalized section[a]

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Soil, clay, sand and gravel	230	230
Silurian system		
Niagaran limestone		
Dolomite, light gray to gray, fine grained to subcrystalline	110	340

Log of well owned by Wisconsin Condensed Milk Co.—Concluded

Description of strata	Thickness *Feet*	Depth *Feet*
Shale, chocolate colored	20	360
Dolomite, light gray to straw color, subcrystalline	50	410
Ordovician system		
Maquoketa shale		
Shale, gray to drab, dolomitic	10	420
Dolomite, drab, granular	20	440
Shale, gray	10	450
Dolomite, gray, shaly	10	460
Shale, light gray	10	470
Dolomite, light gray, with drab shale	20	490
Shale, gray to drab	50	540
Galena-Platteville limestone		
Dolomite, gray to straw color, crystalline	300	840
St. Peter sandstone		
Sandstone, gray to white	30	870
Dolomite, light gray, fine grained, sandy	20	890
Sandstone, white; grains of medium size, clear, rounded	150	1040

[a] The detailed log of this well compiled from study of samples is to be found in the Survey files if desired for reference.

GURNEE

A 1,580-foot well was drilled in 1912 for the Bowman Dairy Company. The water level at that time was just at the surface, or at an altitude of about 670 feet. There are no further data.

Shallow, flowing wells are obtained in the village from the drift and bed rock; the collecting area is probably the higher region to the east. The water is somewhat sulphurous.

HIGHLAND PARK

The source of the public water supply is Lake Michigan. The deep wells owned by the city have been abandoned for a number of years.

The analysis is given of the water from a flowing well at the Tillman farm, one and a half miles west of Highland Park. This is a 2-inch driven well, 180 feet deep and penetrates the Niagaran limestone for 15 feet. The water will flow at the rate of 2 gallons per minute, but the pressure is shut in, so that only about 450 gallons per day is delivered. The water is bottled and sold in the vicinity for drinking purposes. There is enough hydrogen sulphide present to give the water a slight sulphur taste as it comes from the well, but this is rarely noted after the water has been bottled. The water is rather hard, but is preferred by many to that obtained from the lake.

The analysis indicates that a similar water is obtained from the well owned by R. Tillman. The location is across the road and only a few

hundred feet from the previously described well at the Tillman farm.

The Chicago and North Western Railway Company has drilled a 1,760-foot well at their Blodgett watering station, about a mile west of Highland Park. The geological succession, as indicated by the driller's record is shown in the accompanying log. A 16-inch casing extends from the surface to a depth of 121 feet, and 770 feet of 10-inch casing extends from 288 feet to 1,058 feet. The water from the St. Peter sandstone is therefore shut out, but it is possible for Niagaran limestone water to enter.

The analysis indicates a water of low mineral content; a very similar water is furnished by the 498-foot Niagaran limestone well at Lake Bluff. The water tastes strongly of hydrogen sulphide in which it resembles other waters from the bed rock in this region. The yield is about 300 gallons per minute for about 5 hours per day; neither the water level nor effects of pumping are known.

Log of Chicago and Northwestern Railway Company at Blodgett in the SW. 1/4 NW. 1/4 sec. 27, T. 43 N., R. 12 E.

Elevation—650±feet

Description of strata	Thickness Feet	Depth Feet
Clay, yellow	20	20
Clay, blue	60	80
Hard pan	40	120
Limestone	240	360
Shale	15	375
Limestone	25	400
Shale	85	485
Limestone	320	805
Sandstone (St. Peter)	95	900
Sandstone and shale (St. Peter)	133	1033
Shale, red	25	1058
Limestone	10	1068
Limestone and shale	57	1125
Sandstone	30	1155
Shale	25	1180
Limestone	20	1200
Sandstone and shale	130	1330
Limestone and shale	130	1460
Sandstone and shale	100	1560
Limestone	10	1570
Shale and sandstone	30	1600
Shale and sandstone	40	1640
Sandstone	40	1680
Shale	5	1685
Sandstone	75	1760

HIGHWOOD

The municipal supply is lake water obtained from the Highland Park pumping station. A 1,753-foot well has been drilled for the Chicago and Milwaukee Railroad Company; the strata penetrated are similar to those at Blodgett. The well is operated only a few hours per day at the rate of about 75 gallons per miunte.

LAKE BLUFF

The village has 3 deep wells, the depths of which are 300, 498, and about 1,900 feet. The chief sources of supply are the 498- and 1,900-foot wells, as the other one is rarely used. The 498-foot well is cased to bed rock with 194 feet of 10-inch pipe, and the diameter at the bottom is 8 inches; the yield is about 55 gallons per minute. The deeper well is over 30 years old, and the exact dimensions are not known; however, a yield of 75 gallons per minute can be obtained. The original static head was about 45 feet above the surface, or at an altitude of approximately 725 feet. The present level is 45 feet below the ground; the effects of pumping are not known.

The water from the shallower well is softer than that from the deeper one and is therefore preferred. The temperature of the water from the 498-foot well was 52.5° F. and that from the 1,900-foot well was 63.7° F.

LAKE FOREST

The city supply is drawn from Lake Michigan, but a few deep wells have been drilled at neighboring country estates of Ogden Armour, R. S. Moore, Miss Culver, Hobart Taylor, and Alfred L. Baker.

There are 2 deep wells at the Armour estate about two and a half miles west of Lake Forest. The old well is 1,623 feet deep and delivers about 200 gallons per minute. The analysis indicates a fairly hard water; an odor of hydrogen sulphide indicates that probably some additions are received from the Niagaran limestone.

A new 1,920-foot well is cased with 164 feet of 21-inch surface pipe, and 90 feet of 18-inch casing extends through Maquoketa shale. The water level is 42 feet below the surface, or at an altitude of 648 feet. The yield on a 30-hour test was between 400 and 500 gallons per minute; the amount of recession during pumping is not known.

In drilling the new Armour well a small flow of gas was obtained just below the contact of the drift and bed rock, or at a depth about 147 feet. The flow on July 6, 1915, was 218 cubic feet per hour, and the pressure was 1.5 pounds per square inch. The gas was cased off, and the drilling continued. The analysis made by Paul Rudnick of Armour and Company is given below.

Analysis of gas at Armour well, Lake Forest

	Per cent
Methane (marsh gas)	81.5
Ethane	2.5
Inert gases	16.0
Total	100.0
British thermal units per cubit foot	910.

In drilling a 264-foot well on the same property, the well driller reported finding in the drillings from the Niagaran limestone gobs of a dark-colored substance resembling crude oil which would burn when thrown on the fire. The Niagaran limestone in other localities, as in the Chicago area, shows dark-colored, bituminous blotches. The presence of this substance may account for the noticeable content of hydrogen sulphide in the Niagaran limestone waters.

Log of well on estate of Ogden Armour, near Lake Forest, in the SW. 1/4 SE. 1/4 sec. 36, T. 44 N., R. 11 E.

Elevation—690± feet

(Drilled in 1915-16 by Whitney Well Co., Chicago)

Generalized section[a]

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and recent		
Soil, sand, and gravel	147	147
Silurian system		
Niagaran limestone		
Dolomite	253	400
Ordivician system		
Maquoketa shale		
Shale	167	567
Galena-Platteville limestone		
Dolomite, light gray to cream colored, subcrystalline	308	875
St. Peter sandstone		
Sandstone	35	910
Dolomite	20	930
Sandstone	90	1020
Prairie du Chien limestone		
Chert, white, with shale and dolomite, and some sand	60	1080
Dolomite, light gray to cream colored, subcrystalline	80	1160
Dolomite, light, reddish brown, subcrystalline, sandy, glauconiferous; and dolomitic sandstone	80	1240
Cambrian system ?		
"Potsdam" group		
Sandstone, white, with occasional dolomite and shale layers	680	1920

[a] The detailed log of this well, compiled from study of samples, is to be found in the Survey files if needed for reference.

A 1,991-foot well was drilled in 1913 for R. S. Moore at Lake Forest. To obtain a water of low mineral content and no hydrogen sulphide, the water pipe was continued to a depth of 1,660 feet and sealed with a rubber packer. Analysis of the water made by the Dearborn Chemical Company is appended; a moderate amount of hardness is indicated. The water is reported to have no order or taste of sulphur.

LAKE ZURICH

The village water supply is furnished by a 218-foot drift well. The entire distance is cased with 6-inch pipe. No accurate log was kept, but the material was reported to be entirely sand and gravel below a depth of 100 feet. The water level at rest is 100 feet below the surface, but the effects of pumping are not known. The average daily consumption is 4,000 gallons.

The appended analysis indicates a sulphate water with so great a content of calcium and magnesium that large amount of tenacious scale would be formed if the water were used for boiler purposes.

LIBERTYVILLE

The public supply is furnished by 3 drift wells, 2 of which are 180 feet and the other 170 feet in depth. The dimensions range from 4 to 8 inches. Two of the wells are equipped with air-lift pumping systems for use during periods of exceptionally heavy demand. The average daily consumption is about 60,000 gallons.

Other wells in the vicinity are flowing and the collecting area is probably the higher region to the west. Some of the water from the private, flowing wells is bottled and sold. The water is rather hard and must be treated before it is satisfactory for boiler purposes.

RAVINIA PARK

The water supply for the Park is furnished by a 1,096-foot well that pentrates the St. Peter sandstone. The well is 8 inches in diameter at the surface and yields 75 gallons per minute.

The analysis of the water is given, but it is not possible to say that this water is entirely from the St. Peter sandstone. The surface casing extends through the drift, or to a depth of 161 feet, but this does not preclude the entrance of Niagaran limestone water. The mineral content is rather high, and there is a considerable amount of scale-forming solids.

RONDOUT

The Chicago, Milwaukee, and St. Paul Railway Company has a 900-foot well in the St Peter sandstone. This water-bearing formation

was struck at a depth of 870 feet; the curb elevation is approximately 685 feet. The water pipe extends to a depth of 300 feet, and the well is finished at 5 inches. The yield is not known.

The total mineral content is 33.5 grains per gallon of which 22 grains are the carbonates of calcium and magnesium and the sulphate of magnesium. The water is used in locomotives after some softening.

WAUKEGAN

The municipal water supply was formerly obtained from 3 deep wells, but these were abandoned in 1894, and lake water has since been used. The use of the well waters was discontinued because of the hardness which made it unsuitable for boiler use.

A 2,200-foot well is located near the Chicago and North Western Railway station at the foot of the bluff, so that the altitude (about 600 feet) is at least 50 feet lower than that of the land to the west. The well flows about 10 gallons per minute at an elevation of 3 feet above the surface; the dimensions and amounts of casing are not known. The analysis indicates a rather hard water; no trace of hydrogen sulphide was noted.

Flowing wells from the drift or Niagaran limestone are also obtained along the lake flats, as illustrated by those at the North Shore Gas Company. This firm has 2 wells, one of which is 82 feet in depth and does not penetrate bed rock. The diameter is 6 inches and a flow of about 6 gallons per minute is obtained; the static head is about 2 feet above the surface. The other well is 145 feet deep. There is 115 feet of 8-inch casing which rests probably on the bed rock. The flow is approximately 10 gallons per minute and the static head about 10 feet above the surface. The analyses indicate similar waters that are moderately hard and are softened before using in boilers. A very slight trace of hydrogen sulphide was thought to be present in the water from the 145-foot well; none was noted in that from the other well. The water temperature of the shallow well was 54.2° F. and of the other 54.6° F.

ZION CITY

In 1901 and 1902 the city dilled 3 wells that range in depth from about 1,440 to 1,568 feet. Two of the wells are located near the station at an altitude of approximately 595 feet, and the other one is about three-quarters of a mile to the west at an elevation of about 648 feet. The driller's record of the latter well is given below.

Log of well at Shiloh Park, Zion City.

Elevation—648± feet

Description of strata	Thickness Feet	Depth Feet
Clay, sand, and gravel	113	113
Limestone	337	450
Shale	100	550
Limestone	90	640
Shale, red; probably shaly limestone	135	775
Limestone	75	850
Sandstone (*St. Peter*); overflow at 925	190	1040
Marl, red	20	1060
Sandstone and red marl	50	1110
Marl, red	25	1135
Sandstone and red marl	25	1160
Sandstone	125	1285
Shale, blue	105	1390
Sandstone	60	1450
Sandstone and limestone	40	1490
Sandstone	10	1500
Marl, red	20	1520
Sandstone and red marl	10	1530
Marl, red	5	1535
Sandstone	34	1569

All these wells flow at the present time, but since the wells were drilled the static head has receded from 25 to 30 feet. The 1,569-foot well, which is at the highest elevation, flows at the rate of approximately 200 gallons per minute, but the head is only a few feet above the surface. A large portion of the city, and particularly the business section, is situated at an elevation about 20 feet lower than the curb of the 1,569-foot well. The water therefore flows directly into the mains, and the pipe pressure is hydrostatic. The lowering of the water table has made the pressure in the mains very low in many parts of the city. The analyses indicate a rather hard water that would require softening to make it satisfactory for boiler use.

LA SALLE COUNTY

Physiography

LaSalle County is situated in the north-central part of the State; the counties of Bureau and Putnam adjoin it on the west, and the counties of Kendall and Grundy on the east. It is next to the largest county in the state and has an area of 1,146 square miles.

The county as a whole is a flat, upland area which has an average altitude of 650 to 750 feet. However, the continuity of this plain-like region is interrupted by prominent topographic features. The chief of

these is Illinois Valley, which divides the county in an east-west direction into two nearly equal parts. The Illinois has here formed a valley about 2 miles wide and 200 feet deep. The major tributaries of this stream, particularly Vermilion and Little Vermilion rivers, have likewise carved gorge-like canyons near their mouths. The bed rock has been cut deeply, so that precipitous bluffs border the streams.

Another prominent topographic feature is the Marseilles terminal moraine, that enters the county along the eastern border from the southwest corner of Kendall County. This elevated belt then swings southwestward, is cut by the Illinois between Marseilles and Ottawa, whence it swings somewhat to the east and crosses the southern border of the county a few miles east of Streator. This ridge has a width of 5 or 6 miles and an average altitude along its crest of about 750 feet. The differences in elevation between points on the moraine and those on the plains to the west are from 75 to a 100 feet or more. The slopes, however, are gentle; the topography of this elevated belt is somewhat of a knob-and-kettle character and some of the saucer-like depressions are not well drained.

Another morainic belt, called Farm Ridge, emerges from the Marseilles moraine south of Grand Ridge. It extends east and northeast immediately east of Vermilion and Little Vermilion rivers, but north of the Illinois is interrupted by gaps. The width is scarcely over a mile, but in places it has a clearly defined terminal-moraine topography.

The extreme northwest corner of the county is crossed by the Bloomington morainic system. The elevations along its crest are nearly 900 feet. This gives a difference in elevation in the count of about 450 feet, as the lowest altitude of the Illinois is approximately 450 feet.

The entire county lies in the drainage basin of the Illinois which is the master stream of this region. The river flows across the county in a westward direction, a little south of its mid-latitude. The important tributaries in this area are the Vermilion, the Little Vermilion, and Fox rivers. The northern half of the county is drained on the west by the Little Vermilion and on the east by Fox River. South of the Illinois and Vermilion is the important stream. A few minor tributaries drain the area immediately bordering Illinois River. The county, as a whole, is rather well drained although marshes exist around some of the headwaters of the upland creeks. The flatness of the upland prairies prevents rapid run-off during heavy rains.

Geology

The greater part of this county is covered by a mantle of glacial deposits, or till, although the major streams have cut valleys deeply into the

bed rock. The thickness of this surface deposit varies greatly in different parts of the area. Many of the wells in the uplands enter rock at depths of 50 feet and less, except in the northwestern, eastern, and southeastern elevated partions of the county. The average depth to rock in 55 deep wells on the uplands and 8 wells in the valleys is 99 feet. The average depth of 85 other wells situated mainly along the Marseilles moraine is 89 feet.[1]

Along the Bloomington morainic system in the northwestern corner of the county, the drift has a thickness of over 200 feet. Likewise in the area of the Marseilles moraine the depth to bed rock is about 200 feet. In the southwestern township drift thicknesses of 150 feet are not uncommon.

The noteworthy feature of the rock formations in this county is their structure. In other parts of northeastern Illinois, the strata are nearly horizontal, whereas at LaSalle they have been sharply bent into an anticline or fold. This anticline is step-like so that the beds of the crest have an eastward dip, whereas immediately west of the anticline the strata plunge downward at a very high angle before they again rise toward the west.

Along the crest of this fold which is commonly spoken of as the La Salle anticline the later-deposited formations have been removed by erosion so that the older beds are exposed. Indeed beds outcrop here which in regions east and west of the north-south fold are hundreds of feet below the surface; for example at La Salle the strata that outcrop along the top of the anticline are over 1,500 feet below the surface about a mile and a half to the east. From this maximum depth, the beds again rise gradually toward the west.

The trend of the anticline just east of La Salle is about N. 27° W. North of that city it swings a few degrees to the west; in the vicinity of Lowell, the direction is nearly north and south.[2]

The Galena-Platteville limestone is the bed rock formation in the greater part of the northern one-third of the county; in the other two-thirds, the Pennsylvania strata underlie the drift, except for the outcrops of the St. Peter sandstone and Prairie du Chien limestone along the crest of the La Salle anticline and in the major stream valleys.

The character of the deeper strata can be determined from the different logs. The great thickness of the Prairie du Chien group which includes the New Richmond sandstone is to be noted. This sandstone

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[1] Leverett, F., The Illinois Glacial Lobe: U. S. Geol. Survey Monograph 38, p. 635, 1899.

[2] Cady, G. H., Geology and mineral resources of the Hennepin and La Salle quadrangles: Ill. State Geol. Survey Bull. 37, 1919.

has a thickness of 188 feet at Deer Park, according to a well-driller's log, but thins rapidly toward the east and west. A sandstone, probably the New Richmond, is given in the well log from Ottawa which has a thickness of 87 feet. A similar sandstone, 80 feet thick, was reported from the well at St. Bedes College, a little over a mile west of Peru.

Underground Waters

SOURCES

The chief sources of the ground water are the drift, Galena-Trenton limestone, St. Peter sandstone, Prairie du Chien and Lower Magnesian group, and to some extent the Pennsylvanian series. The city wells at Ottawa penetrate the "Potsdam" sandstone.

In the parts where the drift is heavy, as along the morainic areas, the greater number of private wells obtain water from this deposit. In the northern half of the county, where the St. Peter sandstone is within a few hundred feet of the surface, a number of wells tap this stratum. Along the Illinois both the St. Peter and the New Richmond of the Prairie du Chien group are important sources of ground water.

Flowing wells from sand and gravel beds in the drift have been obtained in the vicinity of Earlville and also along the borders of the Marseilles moraine. Springs occur along the valley of the Illinois and its large tributaries, as the Fox, Vermilion, and Little Vermilion.

Several of the deep-lying strata contain water under sufficient hydrostatic pressure to create flowing wells in the regions of low altitude that prevail along Illinois valley. The wells, as a rule, have only a small amount of casing, so that it is not always possible to determine which of the strata are water bearing. Flowing wells are obtained from the St. Peter at altitudes from about 500 feet at Marseilles to about 550 feet at Peru. The greatest head of the St. Peter water noted in the county was at Mendota where it was 68 feet below the surface or at an altitude of about 680 feet; however, this pressure is possibly influenced by waters from upper strata.

The water from the New Richmond has a head a few feet greater than that of the St. Peter at Utica; this formation has a head of about 520 feet and yields flowing wells. In the recently completed well of the Illinois Zinc Company at Peru, the static head was 30 feet above the surface or at an approximate altitude of 493 feet. The greater part of this water is probably from the New Richmond sandstone.

The Cambrian sandstones have been penetrated at Ottawa. The city wells, which are 1,200 feet deep, will flow to a height of a foot above the surface, or at an altitude of 485 feet. The flowing Catlin well at Ottawa is 1,840 feet deep; its static head is about 517 feet.

There is a 2,496-foot flowing well at Streator; the curb elevation is approximately 618 feet. The water is too highly mineralized to be used.

CHEMICAL CHARACTER

A number of analyses of the ground waters in this county are given which will indicate the character of the waters from the different strata. In the northern half of the county the water from the Galena-Platteville limestone and the St. Peter sandstone is of good quality and only moderately mineralized. In the vicinity of Wedron, Ottawa, and Marseilles, the St. Peter water is somewhat sulphurous. In these localities this sandstone is not far below the Pennsylvanian system, or else these rocks occur in the neighborhood, and very probably affect the St. Peter water. The St. Peter water at Streator is very sulphurous and contains a large amount of the alkalies.

The Pennsylvanian rocks, as well as the Niagaran limestone which in places underlies them, usually yield sulphurous waters which are more or less saline. These should be cased off so as not to contaminate the better waters from lower depths.

The water from the New Richmond sandstone is only moderately mineralized as seen by the analyses from Utica. The Ottawa city wells probably obtain their greater supply from one of the upper "Potsdam" sandstones; the mineral content is low.

Most waters from depths greater than 1,700 are rather highly mineralized as shown in the analyses of the waters from the Catlin well at Ottawa and the 2,496-foot well at Streator.

LOCAL SUPPLIES

CEDAR POINT

The village supply is furnished by 1,749-foot well owned by the La Salle Carbon Coal Company. The St. Peter sandstone was struck at a depth of 1,610 feet, or at an altitude of 957 feet below sea level. The casing continues from the surface to a depth of 900 feet; the diameter of the top is 16 inches, and the bottom, 6 inches. The water rises to within 90 feet of the surface, or to an altitude of 563 feet. The yield during a pumping test was 183 gallons per minute; the recession of the water table was not noted.

DEER PARK

Eight wells ranging in depth from 154 to 631 feet are distributed within an area of one and a half by three quarters of a mile. These wells are similar in size and capacity to those at Utica except that the head is somewhat lower. The chief water-bearing formations are the St.

Peter and New Richmond sandstones. The latter formation has a reported thickness of 188 feet, which is the maximum noted in this area.

Log of well at Deer Park on bank of Vermilion River, center SE. 1/4 sec. 30, T. 33 N., R. 2 E.

Elevation—660± feet

Description of strata	Thickness *Feet*	Depth *Feet*
Surface material	3	3
Limestone	47	50
Fire clay	2	52
Sandstone (*St. Peter*)	197	249
Limestone	173	422
Sandstone (*New Richmond*)	188	610
Limestone	21	631

EARLVILLE

The greater number of farm wells in this vicinity are drilled to the St. Peter sandstone, which is found within 200 or 300 feet of the surface. In places the St. Peter has been reported to underlie the drift directly, no Galena-Platteville being present.

The village water supply is furnished by 3 wells, 2 of which are 150 feet deep, and the other, a new one, is 625 feet. The 150-foot wells are 10 inches in diameter and have a combined pumpage of 250 gallons per minute. The new well is 16 inches in diameter at the surface, but its yield is not known. The average daily consumption for the village is 84,600 gallons.

GRAND RIDGE

The drift is very heavy in this vicinity, as the location is on the slope of the Marseilles morainic system. The village well, which is 160 feet in depth, does not reach rock. It is also reported that the sand and gravel bed struck at about 150 feet continues to 195 feet, below which there is blue clay to at least 250 feet.

Log of village well at Grand Ridge

Elevation—652± feet

Description of strata	Thickness *Feet*	Depth *Feet*
Soil	3	3
Clay, yellow	7	10
Clay, blue	105	115
Sand, no water	10	125
Sand and gravel; contains water	35	160

The village well was drilled in 1914 at a cost of $568 which included 156 feet of 10-inch casing with a 14-foot screen at the bottom. The

pumping equipment is an electrically driven, double-action, deep-well pump with a 5¾-inch cylinder; the cost, including motor, was $2,043.

The water level on the completion of drilling was 37.5 feet below the surface. No lowering of the water table was noted after a 22-hour test of 70 gallons per minute. However, it was not possible to make the measurement until 1.5 hours after the cessation of pumping.

The water has a low mineral content and would form only a small amount of soft scale if used for boiler purposes. The temperature was 53.2° F.

LA SALLE

The source of the municipal water supply is 3 wells that range from 7½ to 14 feet in diameter and are about 40 feet deep. The location is along the Illinois bottom flats and at no great distance from the water's edge. The analysis given indicates a rather hard water.

The Matthiessen and Hegeler Zinc Company completed a 1619-foot well in 1913. The water pipe is 8-inch and extends from the surface to a depth of 1030 feet where it is sealed with a special packer. This casing excludes the salt water from the Niagaran limestone and the Pennsylvanian series. The chief sources of the water are the Galena-Platteville limestone and the St. Peter sandstone. The water level at the completion of the well was 65 feet below the surface, or at an altitude of 520 feet. The pumpage is about 150 gallons per minute continuously but the recession while pumping is not known. The water contains considerable mineral matter, of which the greater amount is the salts of sodium. However, the content of calcium and magnesium salts is not low, and it is reported that the scale formed is very hard.

LELAND

The village water supply is obtained from a 230-foot well which probably penetrates the St. Peter sandstone. A 10-inch surface pipe extends to a depth of about 100 feet; the diameter at the bottom is probably 8 inches. The water level at rest is 8 feet below the surface, but the effects of pumping are not known. However, the deep-well pump, which is operated only a few hours at a time, delivers 225 gallons per minute.

The analysis indicates a water with only a moderate amount of dissolved solids; if used for boiler purposes only a small amount of scale would be formed.

LOSTANT

The village has a dug well which is 70 feet deep and 5 feet in diameter. The material penetrated was practically all blue clay until the sand and gravel water-bearing stratum, was struck at 70 feet. The nor-

mal water level is 35 feet below the surface, but it can be lowered nearly to the bottom after pumping for an hour at the rate of about 70 gallons per minute. The recovery requires about two and one-half hours. The water is used primarily for fire protection as the supply is inadequate for other uses. There is no mineral analysis.

MARSEILLES

The source of the public supply is 2 wells that are 600 and 800 feet in depth. The water-bearing formations are the St. Peter and underlying strata, which may include the New Richmond standstone. Both wells will flow, but the 600-foot well at the higher elevation, at an altitude of about 505 feet, is equipped with an air-lift pumping system. The 800-foot well flows about 45 gallons per minute, and the other one 12 gallons. The 600-foot well will pump 67 gallons per minute with the present equipment. The dimensions are probably 8 inches in diameter at the surface, and 6 inches at the bottom. The analyses given is of the combined waters, as it was not possible to secure separate samples. The water is moderately hard, and it is advisable to soften it before using in boilers.

Among the flowing St. Peter wells in the city are those owned by the Howe and Davidson Paper Mills, the Crescent Paper Company, and E. T. Hanshue. These wells vary in diameter from 1¼ to about 3 inches, so that the yields are low. The chemical character is indicated by the analyses. All the waters have a noticeable hydrogen sulphide content. This is particularly true for the shallow well at the Howe and Davidson Company. There has been a recession of at least 15 feet in the head of the St. Peter water during the past 20 years.

A number of years ago a 2,283-foot well was drilled on the farm of R. N. Peddicord about 3 miles north of Marseilles. The driller's log is here given.

Log of an artesian well on the farm of R. N. Peddicord in the SW. 1/4 NE. 1/4 sec. 32, T. 34 N., R. 5 E., near Marseilles, La Salle County

Elevation of the surface about 710 feet above sea level

Description of strata	Thickness *Feet*	Depth *Feet*
Pleistocene and Recent		
Soil and drift	165	165
Pennsylvania system		
Shale (till ?)	9	174
Sandstone	8	182
Shale	10	192
Shale, hard	7	199
Sandstone (sand and gravel)	70	269
Shale	65	334

Log of the Peddicord well—Concluded

Description of strata	Thickness *Feet*	Depth *Feet*
Ordovician system		
Galena-Platteville limestone	25	359
St. Peter sandstone	195	554
Prairie du Chien formation		
Sandstone, calciferous	50	604
Sandstone	45	649
Limestone	265	914
Sandstone, calciferous	25	939
Limestone	72	1011
Sandstone, hard	15	1026
Limestone	95	1121
Shale, blue	73	1194
Limestone	34	1228
Shale	3	1231
Limestone	20	1251
Cambrian system		
Sandstone	15	1266
Sandstone, white	265	1531
Limestone	152	1683
Shale, blue	50	1733
Shale, red	5	1738
Shale, blue	60	1798
"Slate"	112	1910
Shale	9	1919
Limestone	20	1939
Sandstone	214	2153
Limestone	5	2158
Sandstone	125	2283

MENDOTA

The public water supply is furnished by 2 wells in the St. Peter sandstone. The depths are 478 and 490 feet. The driller's log of the deeper one is given below.

Log of city well at Mendota

Elevation—752± feet

Description of strata	Thickness *Feet*	Depth *Feet*
Soil, black	2	2
Clay, yellow	10	12
Clay, yellow; and gravel	3	15
Clay, blue	35	50
Gravel	4	54
Clay, blue	31	85
Sand and gravel	6	91
Clay, blue	40	131
Sand	4	135
Gray, boulder clay with streaks of sand and gravel	25	160
Limestone	280	440
Sandstone (*St. Peter*)	50	490

The surface diameters of the wells are probably 8 inches, and at the bottom, 6 inches. The wells are equipped with air-lift pumping systems, and the combined pumpage is about 460 gallons per minute. The average daily pumpage during July, 1915, was 550,000 gallons, which was pumped in about 20 hours. The water level at rest is 73 feet below the surface, or at an altitude of 679 feet; on pumping the level recedes to 103 feet. The static head has receded about 25 feet during the past 20 years.

The Chicago, Burlington, and Quincy Railroad and the Illinois Central Railroad have wells which are 480 and 563 feet in depth, respectively. The analyses of these waters, besides that of the city well water, are given, and it is noted that they are similer. The mineral content chiefly carbonates of calcium and magnesium, is low. However, the water is softened somewhat for locomotive use by both railroad companies.

The well owned by the Chicago, Burlington and Quincy Railroad is cased to bed rock with 136 feet of 8-inch pipe; the remainder of the bore is 6 inches in diameter. This well will deliver nearly 300 gallons per minute; the average rate of pumpage is about 175 gallons. The water level is similar to that at the water works; the effects of pumping have not been determined.

OGLESBY

In 1915 the village completed a 1,645-foot well, the chief water-bearing formation being the Galena-Platteville limestone and the St. Peter sandstone. The latter formation was encountered at a depth of 1,542 feet or 900 feet below sea level. No appreciable amount of water was obtained above a depth of about 815 feet. Here a small yield of a salty character was struck in the Niagaran limestone. The well was cased from the surface to a depth of about 880 feet; the diameter at the surface is 14 inches and at the bottom, 8 inches. The water level on completion was 103 feet below the ground surface or at an altitude of approximately 539 feet. The pumping machinery has not been installed, but a 13-hour test was made in June, 1915, with a temporary equipment. A yield of 180 gallons per minute was obtained, but the recession during pumping was not determined.

The Chicago Portland Cement Company also has a St. Peter well, which is 1,570 feet in depth. The record of the different strata as determined from a study of the drillings is given.

In drilling this well salt water was struck at a depth of 585 feet, or immediately below the Pennsylvanian system. The head was sufficient to raise the water within 180 feet of the surface. In order to shut out this and any similar water from the Niagaran limestone, the well was completely cased from the surface to a depth of 1,050 feet. The surface diameter is 10 inches and the lower casing is 6 inches.

Log of the Chicago Portland Cement Company's deep well at Oglesby
Elevation—605± feet

Generalized section [a]

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Clay, sand, and gravel	64	64
Pennsylvanian system		
Shale, with occasional thin beds of limestone coal at 320 feet	516	580
Silurian system		
Niagaran limestone		
Limestone	290	870
Dolomite	115	985
Ordovician system		
Maquoketa shale		
Shale, calcareous, and limestone	75	1060
Dolomite, gray (?)	65	1125
Shale, gray (?)	25	1150
Galena-Platteville limestone		
Dolomite, gray	40	1190
Limestone, gray	340	1530
St. Peter sandstone		
Sandstone, gray and white	40	1570

[a] The detailed log of this well compiled from study of samples is to be found in the Survey files if desired for reference.

OTTAWA

The municipal water supply is furnished by 4 wells about 1,200 feet deep, except one which is 1,449 feet. There are also 2 other deep wells which have been abandoned.

The wells were drilled in 1894 to about the bottom of the St. Peter sandstone. In 1896 one of the wells was deepened to 1,500 feet; the driller's log is here given:

Log of city well at Ottawa
Elevation—484 feet

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Soil and yellow clay	9	9
Ordovician system		
St. Peter sandstone	155	164
Prairie du Chien group		
Shale, blue	5	169
Limestone	124	293
Sandstone (New Richmond)	87	380

Log of well at Ottawa—Concluded

Description of strata	Thickness *Feet*	Depth *Feet*
Limestone	430	810
Shale, blue	110	920
Limestone	40	960
Cambrian system		
"Potsdam" group		
Sandstone	160	1120
Sandstone and blue shale mixed	85	1205
Shale, blue	244	1449

The exact size of this well is not known, but it is probably 8 inches at the surface and 6 inches at the bottom. When drilling, the water from the 87-foot sandstone at 293 feet, overflowed at the rate of 25 gallons per minute. As the drilling progressed, the static head increased, so that at 810 feet the flow was 300 gallons per minute. At 1,120 feet the rate of flow was 400 gallons per minute, but no increase was noted between 1,120 and 1,449 feet. The maximum static head was 22.4 feet above the surface, or at an altitude of 506 feet.

Salt water was struck at a depth of 1,500 feet, so that the well was later filled up to a depth of 1,449 feet. The other wells were therefore drilled to a depth of only 1,200 feet.

It is thought that the wells are cased with 6-inch pipe to a depth of about 285 feet, an arrangement that would shut out the St. Peter water. The pumpage from the 4 wells during the summer is about 740 gallons per minute. The water level at rest is approximately a foot above the surface, or at an altittude of 485 feet. This is a recession of 21 feet during the past 20 years. The lowering while pumping is not known, but the recovery is effected in a short time after the pumping has ceased. The water contains only a moderate amount of dissolved mineral solids and is not sulphurous.

Other wells in the city which range up to 500 feet in depth are at the Chicago Fire Brick and Retort Company, Ottawa Brewery, Ottawa Ice and Fuel Company, Federal Plate Glass Company, Twin Bluffs Company, and the U. S. Silica Company. The analyses of the waters from some of these wells are given.

Although the St. Peter sandstone lies only a few feet below the surface in this vicinity, the usual practice is to case off this formation and obtain the supply from the New Richmond sandstone which is reported to be not so mineralized and sulphurous as that from the St. Peter sandstone.

A 1,840-foot flowing well in the northern part of the city is owned by Mr. J. P. Catlin. This well was drilled about 1890, and at that time the static head was estimated to be 195 feet above the surface, or at

an altitude of 705 feet. The flow at the present time is about 3 gallons per minute at an elevation of 7 feet above the well curb and 50 feet distant. The content of sodium chloride, or common salt, is so high that it can be tasted. The analysis is given.

An analysis is also given of the Sanicula Mineral Spring water, which is particularly high in chlorides. This water is bottled and sold in the vicinity. The spring is located at the foot of the bluff on the south side of the Illinois. The water issues from the gravel immediately overlying the St. Peter sandstone. The flow is about 5 gallons per minute.

PERU

The city is situated west of the crest of the La Salle anticline, so that the strata that occur here at depths of over 1,500 feet outcrop a few miles to the east. The geological succession is indicated by the well record from the Illinois Zinc Company.

The public supply is furnished by 4 flowing wells that obtain their major supply from the Galena-Platteville formation, at depths range from 1,225 to 1,505 feet. The static head is only a few feet greater than the curb elevation of 475 feet so that two of the wells are equipped with air-lift pumping systems. Pumping is resorted to only when the consumption exceeds the natural flow. The average daily consumption is 300,000 gallons. The analysis of the water from the 1,505-foot well drilled about 1913, is given. The amount of casing is not known, but it probably extends for some distance into the bed rock, or Niagaran limestone because the water from this formation is salty and must be shut out. In one of the older wells in which the casing has developed leaks, the resulting water is somewhat brackish.

The Illinois Zinc Company has 3 artesian wells, one of which has just been completed. The depth is 1,828 feet, and the New Richmond sandstone has a thickness of 140 feet. The static head of the water from the St. Peter was 14 feet above the surface, or at an altitude of 477 feet. After penetrating the New Richmond, the pressure increased to 30 feet. There are also artesian wells at the two breweries.

The recession of the artesian water table at Peru has been considerable, although the actual amount is not known. The hydrostatic pressure in 1899[1] was estimated to be sufficient to raise the water 85 feet above the curb of the city wells. This is probably 75 feet greater than that at the present time.

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[1] Leverett, F., The Illinois Glacial Lobe: U. S. Geol. Survey Monograph 38, p. 637, 1899.

Log of well owned by Illinois Zinc Co., Peru, in the SW. 1/4 SW. 1/4 sec. 16, T. 33 N., R. 1 E.

Elevation—463± feet

Generalized section[a]

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Alluvium, silt and sand, with pebbles	72	72
Pennsylvanian system		
McLeansboro and Carbondale formations		
Shale, gray to drab, with some limestone near base	86	158
Shale, black, fissile	12	170
Shale, gray to drab, sandy in places	78	248
Shale, black fissile	12	260
Limestone, gray, argillaceous	3	263
Shale, gray, with some coal	70	333
Coal (No. 2), with some shale	8	341
Pottsville formation		
Fire clay	6	347
Shale, black to grayish black	17	364
Sandstone, gray, medium-sized grains	6	370
Shale, greenish gray to gray with coal at base	50	420
Pre-Pennsylvanian (Silurian ? Devonian ? Mississippian ?)		
Shale, gray, calcareous, with some brown shale	151	571
Silurian system		
Niagaran limestone		
Limestone, dolomitic, or dolomite, white	241	812
Ordovician system		
Maquoketa shale		
Shale, gray to drab, dolomitic	164	976
Galena-Platteville limestone		
Dolomite, straw color to tan, finely crystalline	387	1363
St. Peter sandstone		
Sandstone, white, grains rounded, fine to coarse	125	1488
Prairie du Chien group		
Shakopee formation		
Dolomite, sand, and green shale	12	1500
Sandstone, white, calcareous	11	1511
Dolomite, white to brown, sandy and shaly in places	163	1674
New Richmond sandstone		
Sand, colorless, quartz, coarse, rounded	134	1808
Dolomite, white, with a little sand	3	1811
Sand, with a little dolomite	3	1814
Oneota formation		
Chert, white, with gray dolomite	5	1879
Dolomite, white	9	1828

[a] The detailed log of this well compiled from study of samples is to be found in the Survey files if desired for reference.

RANSOM

The village water supply is furnished by a 415-foot drilled well. There is no complete record of the strata penetrated, as the well has been deepened from 274 feet, and no log was kept of this upper part. The log of the lower portion indicates a 37-foot sandstone near the bottom, probably in the Pennsylvanian system, which is the water-bearing bed. The analysis given is of the water when the well was only 274 feet in depth. There is no other analysis.

SENECA

The village has no water works, but there are a number of private flowing wells ranging in depth from 300 to 680 feet. The water-bearing formations are the St. Peter and underlying strata. The static head is only a few feet above the surface or at an altitude of about 510 feet.

The well at the Chicago, Rock Island and Pacific Railroad station is 410 feet deep and the water is used in the locomotives. This is a flowing well, but the water must be pumped into the elevated tank.

SHERIDAN

The village water supply is obtained from a 415-foot drilled well. The New Richmond sandstone is reported to have been struck at a depth of 240 feet and to have been 75 feet thick.

There is also a 748-foot well at Glen Park across Fox River from Sheridan. No accurate record of the strata penetrated was kept, but the chief water-bearing beds are probably the New Richmond sandstone and underlying strata.

STREATOR

The city supply is obtained from Vermilion River, but some of the factories have deep wells.

A number of years ago the city drilled a 2,496-foot well the record of which is given on the accompanying pages. The water is too salty to be used. The original head of the St. Peter water was 40 feet below the surface, or at an altitude of 578 feet. As the drilling continued, the head increased so that at 2,170 to 2,496 feet, the water had a head of 45 feet above the surface. Although the well still flows, there has been a great reduction in the hydrostatic pressure.

The following companies have St. Peter wells in use at the present time: American Bottle Company, Streator Brick Company, Western Glass Company, and the Atchison, Topeka, and Santa Fe Railway Company. These wells are usually completed after the base of the St. Peter sandstone has been reached; the depths range from 560 to 700 feet.

The casing extends down through the Pennsylvanian system, or to the Galena-Platteville limestone, which is about 200 to 225 feet.

None of the wells flow, but the water level is about 100 feet below the surface. In the winter of 1915, the level in the 700-foot well at the American Glass Company was 98 feet below the surface, or at an altitude of 527 feet. The wells are not large, but yields of from 30 to 100 gallons per minute are obtained.

The character of the water is indicated by a number of analyses. The alkali salts dominate, although calcium and magnesium carbonates are also present. The water is strongly sulphurous, and the high content of sodium salts renders it rather unpalatable. An objection to its use in boilers is that it causes considerable foaming; it is, however, used for this purpose at the Western Glass Company without treatment and is considered satisfactory. The temperature of the water at the American Glass Company was 59.5° F. and at the Western Glass Company, 59.7° F.

Log of an artesian well boring at Streator, Illinois

Elevation—623 feet

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent series		
Drift	30	30
Pennsylvanian system		
Shales, limestone, sandstone, and coal	211	241
Ordovician system		
Galena-Platteville formation		
Limestone	203	444
St. Peter sandstone	225	669
Prairie du Chien group		
Limestone, white	90	759
Sandstone, white	133	892
Limestone, white	211	1103
Sandstone, white	37	1140
Limestone, dark gray	50	1190
Sandstone, fine, reddish (contained magnetic iron grains)	15	1205
Limestone, dark gray	13	1218
Sandstone, white and brown, mixed	1	1219
Limestone, gray	18	1237
Cambrian system		
Sandstone, white with some brown	168	1405
Shale, blue	100	1505
Limestone, dark	73	1578
Sandstone, dirty brown	21	1599
Sandstone, limy and shaly	2	1601
Sandstone, buff	35	1636
Sandstone, white to buff	77	1713
Sandstone, white	25	1738

Log of well at Streator—Concluded

Description of strata	Thickness *Feet*	Depth *Feet*
Sandstone, red (grains of magnetic iron)	10	1748
Sandstone, dirty brown (10% mag. iron)	17	1765
Lime, soft	60	1825
Shale, blue	13	1838
Shale, brown, sandy, hard	30	1868
Shale, blue, soft	20	1888
Shale, pink	95	1983
Sandstone, dark red	80	2063
Shale, blue	50	2113
Limestone, bluish	50	2163
Sandstone, dark drab	15	2179
Sandstone, reddish buff	35	2213
Sandstone, white	283	2496

UTICA

There are at least 11 flowing wells in the village which derive the greater amount of their supply from the New Richmond sandstone of the Prairie du Chien group at depths ranging from 175 to about 350 feet. The ground elevation varies between 475 and 500 feet, but the static head is about 520 feet.

The village water supply is furnished by 5 wells which range in depth from 225 to 350 feet. Each of the wells has about 140 feet of 4-inch pipe which is directly connected to the distributing system. When the first well was drilled in 1883, the water had a head of 40 feet above the surface but at present it is but half as high or even less.

The analyses of 3 of the waters show that they are practically identical. The chief salts are the carbonates of calcium and magnesium; some soft scale would form if the water were used untreated in boilers.

WEDRON

The St. Peter sandstone outcrops in many places along Fox River and sulphur springs from this formation are numerous. One of the largest of these springs is located about a mile south of Wedron on the east bank of Fox River. The Sulphur Lick Springs Hotel and a number of cottages are situated here. The spring has a flow of 1,050 gallons per minute and has excavated a large pit in the St. Peter sandstone. The flow is utilized to turn a water wheel that operates a pump which raises the water to an elevated storage tank. Sufficient pressure is thus furnished so that the water can be used in all parts of the hotel.

The water contains hydrogen sulphide, but the amount present is not sufficient to give it a disagreeable taste. The chief salts are the carbonates of calcium and magnesium, present in moderate amounts.

McHENRY COUNTY

Physiography

McHenry County has an area of 624 square miles and is situated along the northern border of the State; it is bounded on the east by Lake County and on the west by Boone County.

A large part of the area is at an elevation of 900 feet, and several points along the northern boundary have altitudes of over 1,000 feet making the county one of the highest in the State. Essentially all the county except for a narrow strip less than a township in width on the west border, is covered by a system of moraines formed during the Wisconsin stage of glaciation.[1]

The topography has therefore pronounced morainic aspects; the land is rolling and contains numerous irregular hills and depressions. Some of the upland areas are wooded.

Kishwaukee River and its tributaries which flow westward to Rock River drain the western half of the county. The eastern part is inadequately drained by Fox River and its tributaries through a system of sloughs and small lakes. The porous character of the thick drift covering permits the absorption and retention of much of the rainfall.

Geology

The entire county, except for a few isolated spots in the western portion where the rock outcrops, is covered by a heavy drift deposit. This mantle of clay, sand, and gravel probably averages 200 feet in thickness, or nearly twice the average thickness for the State.

The depths of farm wells which have not struck rock are taken from Leverett's report on the Illinois Glacial Lobe.[1]

Deep drift borings in southeastern McHenry County

	Depth *Feet*
Moses Dimon, 2 miles south of Marengo	125
R. Cooney, sec. 14, T. 45 N., R. 6 E	94
Harmony post office	112
Ira Curtiss, near center of T. 43 N., R. 6 E	180
Well 80 rods east of preceding	86
W. Whittemore, T. 43 N., R. 7 E	100
Mr. Cummings, near Huntley	108
George Bunker, T. 44 N., R. 7 E	84

[1] Leverett, F., The Illinois glacial lobe: U. S. Geol. Survey Monograph 38, 1899.

The following list of depths to bed rock in different parts of the county has ben collected by the writer:

Thickness of drift in McHenry County

	Depth *Feet*
Algonquin, Illinois Condensing Co.	103+
Harvard, Chicago and North Western Ry. Co.	97
Ringwood, Pullman Dairy Co.	215
Woodstock, city well	212

This heavy mantle of drift contains irregular beds of sand and gravel that form reservoirs for the rainfall that has percolated down from the surface. The drainage lines are so poorly developed in many localities that an excessive run-off is prevented. In some places the sand and gravel strata are confined within impervious clay beds; then if the pervious beds are dipping to any extent, artesian conditions will be created. This will in some places give flowing wells from the drift or else produce wells of large yield; springs may be another result of these conditions.

Very little rock outcrops in the county because of the heavy drift deposit. In the western part near Kishwaukee River rock is found at the surface in a few places. The outcrop surfaces, according to Leverett, appear to stand above the general rock surface and probably represent the tops of pre-glacial ridges or hills.

The Niagaran limestone is the bed rock in the greater part of the county. The strata have an eastward and southward dip, so that in the western tier of townships the drift is underlain by the Maquoketa shale. It is also possible that in the extreme western and northwestern parts of the county,erosion, during glacial and pre-glacial times, has removed the Maquoketa shale, so that the underlying Galena-Platteville limestone is the bed rock.

The other formations that have been penetrated by drilling are the St. Peter sandstone, Prairie du Chien limestone, and the "Potsdam" group.

Few deep wells have been drilled in the county, and consequently only a few logs have been obtained. No sets of drillings have been studied, so that nothing can be said regarding the strata more than is indicated by the driller's logs. The St. Peter sandstone is present from 650 to 750 feet below the surface with a thickness of about 200 feet. Variations in the thickness of this formation may be expected and also in the depths at which it is found. As a rule the formations should lie at a greater depth in the eastern and southeastern parts of the county because of their dip in this direction. However, the surface elevations are greater in

the northern area, a difference that may in many places offset to a considerable degree the effect of the dip.

The Prairie du Chien formation seems to be much thinner here than in the counties to the south and southeast, and it has also assumed a more sandy phase. The drillers do not seem to have been able to draw a definite dividing line between this formation and the underlying "Potsdam" sandstones.

Underground Waters

SOURCES

The heavy drift deposit forms such an excellent collecting reservoir for the rainfall that large yields are obtained from many shallow wells. In prospecting for water supplies, these shallow depths should be tested before drilling deeper. The Niagaran limestone below the drift in the greater part of the county also contains water. The St. Peter sandstone can likewise be expected to deliver considerable amounts. Then finally the "Potsdam" group at depths of 1,100 feet and greater have always furnished large amounts of water. The county is therefore fortunate in having a number of possibilities for developing water supplies.

STATIC HEAD

Flowing wells are obtained from the drift at McHenry and Algonquin; there are also good springs at the latter place and at Cary. No flowing wells are reported from the St. Peter and underlying formations, but the water level is in most places within 20 to 100 feet from the surface, so that pumping is not difficult.

CHEMICAL CHARACTER

The only analyses of deep well waters are from Woodstock and these show a moderate amount of mineral salts. There is generally considerable variation in the hardness of waters from the drift wells in different localities. The analyses indicate that the drift waters contain more scale-forming solids than the water of wells, about 1,000 feet in depth but the differences are not great.

LOCAL SUPPLIES

ALGONQUIN

The village water supply is obtained from a number of springs situated on a hillside. Open joint tile are laid at a depth of 4 or 5 feet in one or more rows of approximately a quarter of a mile in length. It is possible to collect about 700,000 gallons per day. The water contains

a rather moderate amount of mineral matter but would form some scale if used untreated in boilers.

A 2,527-foot well was drilled in 1893 for the Illinois Condensing Company. From the very incomplete record of the strata the bottom of the St. Peter sandstone appears to be at 860 feet. Sandstone strata are again mentioned at 1,185 and 1,710, and red sandstone at 2,080 feet which probably continued to the bottom of the well. The water corroded the pipes extensively so that its use was discontinued over twenty years ago.

Flowing drift wells have been obtained in the vicinity at points of low elevation.

CRYSTAL LAKE

The village has a dug well 35 feet deep and 8 feet in diameter; the lining is 2 rows of 4-inch cement blocks. The driller's record is as follows:

Driller's log of well at Crystal Lake

Description of strata	Thickness *Feet*	Depth *Feet*
Soil and clay	2	2
Gravel, coarse	4	6
Gravel, fine, and sand	29	35

The static water level is 16 feet below the surface and lowers only 3 feet after pumping all day at the rate of over 200 gallons per minute. The average daily consumption is 20,000 gallons.

The water contains considerable calcium and magnesium carbonates, and some magnesium sulphate; no hydrogen sulphide was noted in contrast to the rock well water at North Crystal Lake.

HARVARD

The city has two wells, 742 feet and about 1600 feet in depth, but no drilling records seem to have been kept. However, the rock succession can be determined from the driller's log of a well drilled in 1910 for the Chicago and North Western Railway Company.

Driller's log of Chicago and North Western Railway well, Harvard

Elevation—935± feet Description of strata	Thickness *Feet*	Depth *Feet*
Soil, clay, sand and gravel	97	97
Limestone, "chalky"	83	180
Shale, green	75	255
Shale, brown	71	326
Limestone	322	648
Sandstone (*St. Peter*)	187	835
Sandstone, red	55	890
Limestone	10	900
Shale, green	19	919

The water level in this railroad well at completion was 60 feet below the surface; on a pumping test it delivered 310 gallons per minute. The well is 12 inches in diameter at the surface and probably 8 inches at the bottom.

The municipal water plant is located on low land in the southwest part of the city and about 200 feet from a creek. The old 1,600-foot well, which has a diameter of 10 inches at the top and 6 inches at the bottom, is seldom used; the capacity is given as about 200 gallons per minute with the working barrel of the pump at 115 feet. The 742-foot well is 8 inches in diameter at the surface and 6 inches at the bottom; the working barrel is at a depth of 95 feet. The normal water level is 20 feet below the surface but when pumping at a rate of 150 gallons per minute the level recedes to below the pump barrel. The average daily consumption is 200,000 gallons. The water is moderately mineralized and contains some scale-forming solids.

MCHENRY

The village water plant is located in the valley of an intermittent stream tributary to the Fox River lowlands; the river is approximately a quarter of a mile away. Two flowing wells have been obtained from depths of 68 and 72 feet. The wells are 6 and 8 inches in diameter and the water is from a sand and gravel stratum.

The Borden Dairy Company has two wells about 170 feet in depth, but it is not known whether bed rock was penetrated.

MARENGO

The source of the municipal water supply is a dug well 14 feet deep and 20 feet in diameter. The entire depth, except for an upper 3-foot layer of black soil, is through a stratum of sand and gravel. The maximum yield during dry weather is about 100,000 gallons per day. The appended analysis indicates a moderately mineralized water which would form some scale if used for boiler purposes.

The dug wells in the village vary greatly in depth. Those in the gravel plain along Kishwaukee River are only 20 to 25 feet, whereas those on the slope of the moraine in the south part of the village are 60 to 80 and occasionally 125 feet in depth. Bed rock has not been reported.

NORTH CRYSTAL LAKE

The water supply for the village is obtained from a 285-foot well that is said to have penetrated the bed rock to a depth of 25 feet. The diameter is given as 8 inches at the surface and 6 inches at the bottom.

The water level is approximately 60 feet below the surface; at least 225 gallons per minute can be pumped for a number of hours. The amount of recession in the water level at the above pumping rate is not known. The average daily consumption is 55,000 gallons.

The water contains only a moderate amount of mineral matter in comparison with other wells of this depth. No excessive scale would be formed if it were used for boiler purposes. Enough hydrogen sulphide is present to be distinctly noticeable when the water is delivered by the pump. The shallow wells in the vicinity are about 60 or 75 feet deep and draw water from sand and gravel beds in the drift.

RINGWOOD

A well 1,641 feet in depth was recently drilled for the Pullman Dairy Company, but no record of the strata was kept. The depth to bed rock was given as 215 feet.

The water level is reported to be about 80 feet below the surface. No analysis of the water has been made.

WOODSTOCK

Three deep wells ranging in depth from about 1,000 to 2,079 feet have been drilled for the city. The succession of strata as indicated by the driller's log is given.

Driller's log of Woodstock city well No. 2
Elevation—915 feet
Authority: J. P. Miller Artesian Well Co., Chicago

Description of strata	Thickness *Feet*	Depth *Feet*
Soil, clay, sand, and gravel	209	209
Limestone	66	275
Shale	34	309
Limestone, "caves"	81	390
Shale	30	420
Limestone	335	755
Sandy limestone	41	796
Sandstone, hard (*St. Peter*)	139	935
Marl, red	62	997
Sandy limestone	207	1204
Marl and sandstone	48	1252
Limestone and shale	70	1322
Sandstone	74	1396
Limestone	181	1577
Limestone and sandstone	9	1586
Limestone	17	1603
Sandstone, red	207	1810
Sandstone, hard	203	2013
Sandy shale	9	2022
Sandstone, hard	17	2039
Limestone	33	2072
Sandstone	7	2079

The city also drilled two shallow wells in 1913 so that the deep wells are not used now so extensively as formerly. In September, 1914, the water level in the 1,000±-foot well at rest was 50 feet below the surface when the other two wells were idle; the effects of pumping were not known. There has been some recession of the water level, but records have not been kept.

The deep wells are reported to yield from 75 to 160 gallons per minute each; the sizes are not exactly known, but they are probably not over 5 inches in diameter at the bottom.

The two shallow wells belonging to the city are situated in a separate pumping station over a mile distant from the old plant. The land around this No. 2 station is low lying and nearly flat. The wells are 85 feet deep and are each cased with 10-inch pipe to the top of an 18-foot Cook deep-well strainer. Although the wells are only about 15 feet apart they are able nevertheless to deliver 200 gallons each per minute when operating together. The water level at rest is 23 feet below the surface; the operating level is not known.

The Oliver Typewriter Company has two deep wells, one of which is 1,211 feet deep, but the depth of the other is not known, although it is probably about the same. The 1,211-foot well is completely cased from the surface to 980 feet, or to the bottom of the red shale that underlies the St. Peter sandstone; the diameter is 8 inches at the surface, and approximately 5 inches at the bottom. The water level is about 60 feet at rest and about 90 feet when pumping at the rate of 120 gallons per minute.

The analyses of the water from the 1,000±-foot well at the municipal water plant and from the 1,211-foot well at the Oliver Typewriter Company are very similar. Although the water contains a notable amount of mineral matter, it is not too hard to be used for boiler purposes. The shallow-well water is also very similar; carbonates of calcium and magnesium being the predominant salts.

WILL COUNTY

Physiography

Will County adjoins Dupage and Cook counties on the south; the eastern boundary is the Indiana state line. The total area is 844 square miles.

The Valparaiso morainic system crosses the northeastern and eastern portions and the elevations along its crest are the highest in the county. Altitudes somewhat greater than 800 feet are found around Monee, although the average elevations along the ridge are from 750

to 800 feet. The lowest points in the county are in the southwest part along Fox River where elevations of 490 feet occur.

That portion of the county north and east of a line connecting Joliet and Peotone is occupied by the moraines of the Valparaiso system. The surface of this elevated area is somewhat rougher than that of the lower land to the southwest. The topography is undulating with knolls here and there that rise to a height of 15 to 40 feet above the general surface. Shallow basins, many of which are not well drained, are associated with the small hills.

The remainder of the county outside of the morainic area is almost flat except where the streams have eroded. This is particularly noticeable in the southwestern townships in the vicinity of Braidwood. The Desplaines River Valley, which crosses the northwestern part of the county, is a prominent topographic feature. The bottom of this valley, which at one time was the outlet of the waters from Lake Chicago, is at an elevation of 75 to 100 feet below that of the bordering uplands.

The major drainage line is the Desplaines River which flows across the northwest portion of the county in a southwest direction, and drains the area north of about the latitude of Joliet. Dupage River, a tributary of the Desplaines, drains the tier of townships along the northwestern border. The southern and southwestern area is drained by small streams which flow southwestward from the moraines of the Valparaiso system. These streams are tributaries of Kankakee River, which flows northwestward across the southwestern townships. The Desplaines and Kankakee join just beyond the county border to form the west-flowing Illinois River.

Geology

The previously mentioned area occupied by the Valparaiso morainic system has a drift covering that ranges up to 180 feet thick. Leverett[1] considered that the average thickness along the morainic area was about 100 feet. The average depth of 42 wells situated mainly along the Valparaiso moraine was 76 feet and they did not penetrate rock. The average depth to rock in 55 wells on the plain area southwest of the moraine was 43 feet. In the morainic area and along its border the drift contains irregular beds of sand and gravel which renders it possible to secure good wells at shallow depths. The surface waters also find their way down to the underlying, fissured limestone.

Beds of sand and gravel also occur along the valleys and afford favorable conditions for the retention of surface waters.

The Niagaran limestone is the bed-rock formation that underlies

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[1] Leverett, F., The Illinois glacial lobe: U. S. Geol. Survey Monograph 38, p. 649, 1899.

practically the entire county, outcropping at numerous places along the Desplaines. The strata rise towards the west, so that the older Maquoketa shale outcrops along the western border south of about the latitude of Joliet. The Channahon limestone, outcropping near the village of that name, has been described by Professor Savage[1] and referred to the Alexandrian series. This formation is younger than the Maquoketa and older than the Niagaran limestone. It is very probable that the Channahon limestone is present over greater areas, but is concealed by younger deposits.

In the southwestern townships there is a narrow strip of Pennsylvanian strata which probably nowhere in the county attains a width of over five miles. This area of coal-bearing strata extends southward from about where Desplaines River enters Grundy County.

Very few deep drillings have been made in the county so that the depths to the different strata are not known for all localities. The records from Lockport and Joliet indicate a geological succession similar to that at Chicago. However, the combined thickness of the St. Peter and Prairie du Chien formations at Joliet is greater than at Chicago. The combined thickness at Joliet is approximately 700 feet, whereas at Chicago it is only 550 feet.

From Joliet toward the southern city limits of Chicago the St. Peter sandstone has a dip of about 10 feet per mile, whereas the first "Potsdam" sandstone dips only 5 feet to the mile; this is because of the increased thickness of the lower strata at Joliet. In the direction of Kankakee the St. Peter sandstone has a dip of approximately 7 feet per mile. The depth to the St. Peter sandstone will vary in different parts of the county from 600 to 900 feet. The shallowest depths will be in the valleys of the Kankakee and Desplaines in the southwestern townships. The formations will lie at a greater depth on the uplands because of differences in surface elevation. In the townships north of the latitude of Joliet and west of the Desplaines the St. Peter sandstone will be found at depths of 625 to 750 feet. Along the Valparaiso moraine the depths will range up to 900 feet. The first sandstone of the "Potsdam" group should be encountered from 600 to 700 feet below the St. Peter.

Underground Waters

SOURCES

The greater number of municipalities have utilized either the drift deposits or the underying bed rock in the development of water supplies. This should be done wherever it is possible, as the deeper-lying strata

[1] Savage, T. E., Stratigraphy and paleontology of the Alexandrian series in Illinois and Missouri: Ill. State Geol. Survey Bull. 23, p. 26, 1913.

have already been heavily drained. The Valparaiso moranic area and also some miles beyond it, furnish strong supplies of water at shallow depths. The St. Peter and "Potsdam" sandstones have been drawn upon in some of the cities in the western part of the county; those will be discussed under the different localities.

STATIC HEAD

Flowing wells from either the drift or bed rock have been obtained at some places along Desplaines River; springs also occur. The head of these shallow wells is so variable that the water level in one may differ considerably from that in another situated at no great distance.

The static head of the waters from the deeper strata is known only at Joliet, Lockport, and Wilmington. The waters from the St. Peter and "Potsdam" formations have been heavily drawn upon at Joliet, so that there has been a great recession of the water table. The "Potsdam" wells at the Joliet water works in 1899 had a head of about 40 feet above the surface or at an elevation of 575 feet. The St. Peter wells also flowed at this time. The "Potsdam" water level in 1915 was about 85 feet below the surface or at an altitude of 455 feet; in the large city wells the level recedes while pumping to 150 feet and more.

The St. Peter water level at the Joliet School well in 1913 was 148 feet below the surface, or at an altitude of 400 feet; in 1911 the level was reported to be only 50 feet below the surface. At Rockdale about two and a half miles from Joliet High School and the center of the city, the St. Peter water level in September, 1915, was 72 feet below the surface or at an altitude of 476 feet. Two flowing wells at Wilmington each about 800 feet deep, presumably obtain water from the St. Peter; the curb elevation is approximately 550 feet.

CHEMICAL CHARACTER

The water from wells that penetrate the drift and Niagaran limestone is, as a rule, somewhat harder than that from the St. Peter and the first "Potsdam" sandstone, although exceptions occur as water of only a moderate mineral content is furnished by some of the shallow wells.

The analyses of the waters from the St. Peter and "Potsdam" formations are similar. The Desplaines Street well at Joliet supplies a good example of the water from the first "Potsdam" sandstone. The waters from the deep wells at the Citizens Brewery and at the Sehring Brewery are not typical "Potsdam" waters, because the Niagaran limestone waters are not cased off in these wells as in the Desplaines Street

well. These uncased wells are also pumped at a comparatively low rate, so that the greater part of the water obtained is from the Niagaran limestone. The St. Peter wells at Rockdale water works and at Joliet High School are cased to below the Niagaran limestone.

The chief salts in the St. Peter and first "Potsdam" sandstone waters are the carbonates of calcium and magnesium and sodium sulphate. They are only moderately hard, but would form some scale if used untreated in boilers.

Wells 2,000 or more feet in depth are very likely to furnish waters of high mineral content. The well at Lockport was first drilled to a depth of 1,922 feet, but salt water was struck, so that the well later was plugged at a depth of about 1,650 feet.

The waters from the Pennsylvanian strata in the southwestern townships are sulphurous, the water from a shallow well at Custer Park has the high hydrogen sulphide content of 49 parts per million.

LOCAL SUPPLIES

BRAIDWOOD

The drift at Braidwood is probably not over 40 to 50 feet thick. The underlying strata belong to the coal-bearing Pennsylvanian series and yield waters in many places of a sulphurous taste because of the hydrogen sulphide content.

The chief source of the city supply is a dug well 20 feet deep. The dimensions are 6 by 10 feet, and the walls are protected by 2-inch planks. The water is obtained from a sand and gravel stratum near the bottom of the well; the material above this water-bearing bed is for the most part sand. The water level at rest is 8 feet below the surface; the effects of pumping are not known. The average daily pumpage is approximately 7,000 gallons. The water is hard and is not desirable for boiler use without softening. The analysis is given.

The city has also seven driven wells, 12 feet in depth and cased with 3-inch pipe, which have 3-foot strainers at the bottom. Formerly the water supply is reported to have been furnished by a 900-foot well, but the reason for the abandonment of this source is not known. The record of the strata is given below.

Driller's log of city well at Braidwood

Elevation—581± feet

Description of strata	Thickness *Feet*	Depth *Feet*
Quicksand	15	15
Hard pan	6.5	21.5
Clay and bowlders	12.5	34
Clay shale	3	37
Sandstone	10	47
Shale, "slate"	4	51
Clay shale	29	80
Coal	2.7	82.7
Fire clay	3.3	86
Sandstone	6	92
Shale, "slate"	1	93
Coal	.5	93.5
Clay shale	13.5	107
Shale, sandy; seam of fire clay	8.5	115.5
Shale, carbonaceous	.5	116
Fire clay	2	118
Fire clay, nodular	2	120
Shale	3	123
Coal	.5	123.5
Fire clay	1.5	125
Shale, black; "slate"	.5	125.5
Coal	1	126.5
Fire clay	1.5	128
Shale, sandy	12	140
Limestone	20	160
Limestone, fossiliferous	18	178
Limestone	8	186
Shale	2	188
Limestone	35	223
Shale; limestone bands	10	233
Shale, gray; "slate"	20	253
Shale and "slate"	15	278
Limestone	377	645
Sandstone (*St. Peter*)	208	853
Limestone	5	858
Sandstone	2	860
Limestone	40	900

CRETE

The village is situated on the northern half of the Valparaiso morainic system, the crest of which is a few miles to the south. The ground-water conditions are therefore similar to those at Steger.

The source of the village water supply is a 192-foot well situated near the center of the town. The Niagaran limestone was struck at

about 100 feet, and the well is cased with 10-inch pipe from the surface to a depth of about 150 feet. The water level at rest is 30 feet below the surface; the effects of pumping are not known but the working barrel of the pump is placed at 80 feet. The pump is operated for 2 hours per day at a rate of approximately 90 gallons per minute.

The analysis indicates a calcium and magnesium carbonate water somewhat similar to other Niagaran limestone waters of this area. Although the water is not so hard as that from many of the rock wells, of this region, it is nevertheless not advisable to use it in boilers without some softening.

JOLIET

The original water works installation was in 1884 and the source was a group of shallow drift wells. The supply was later increased by the drilling of St. Peter and "Potsdam" wells that ranged in depth from 1,200 to 1,700 feet. This was again supplemented by storage reservoirs that derived water from Hickory Creek. A plan was inaugurated in 1907 for the drilling of isolated deep wells in different parts of the city. The first one drilled was at Crowley and Ottawa streets and this was followed in 1911 by another at Canal Street. Since then, the following wells have been drilled in succession at intervals of about a year: Spruce Slip, Van Buren Street, and Ruby Street. These wells are located at no great distances from the central portion of the city; the maximum distance between any two wells is about two miles, and the average is about half a mile, although the Crowley Avenue and the Canal Street wells are only 700 feet apart.

The geological succession is indicated by the accompanying log that has been compiled from a study of the drillings. The chief water-bearing stratum is the first "Potsdam" sandstone which is struck at approximately 1,325 feet.

The drilling was discontinued after the first "Potsdam" sandstone was passed through; the depths range from 1,547 to 1,563 feet. The wells are usually cased with 14-inch casing through the Maquoketa shale or to a depth of about 325 feet. In nearly all the wells it has been necessary to place some casing in the lower part of the Prairie du Chien formation, as there is a tendency to cave at this horizon. In drilling the Canal Street well an oily and sulphurous water was obtained, which was thought to have its source in the Maquoketa shale. A 10⅝-inch casing was continued through this formation to a depth of 218 feet. As no improvement resulted the casing was extended so that the well is completely cased from the surface to a depth of 893 feet or below the bottom of the St. Peter sandstone. Concrete was also poured into the space between

the casing and the wall of the well; this formed a layer an inch or more in thickness. The well was then pumped for a year at the rate of nearly 1,000,000 gallons per day and the water allowed to run into the river. The oily and sulphurous taste was still noted, and a plant was installed to remove the objectionable matter by aeration.

None of the waters from the other deep city wells have the above-mentioned, disagreeable properties. It was therefore believed that the nearby gas works was responsible. This would be through the downward percolation of surface waters mixed with the gas-house wastes. It is, however, difficult to understand how these surface waters reached the great depth, unless they had access to an old "Potsdam" well, in which case it would be readily possible, as the sulphurous waters of the bed rock would flow into the uncased deep well and therefore affect the waters at the lower horizons. An instance of deep-well waters that developed a sulphurous taste was noted at Blue Island and is discussed under that locality.

The latest well drilled at Ruby Street, is cased with 10-inch pipe to a depth of 1,207 feet. This was because much difficulty was experienced with caving material.

The daily pumpage of each of these isolated city wells is from 500,000 to 1,000,000 gallons. The daily yield from the six old wells and the group of 20 drift wells located at the old pumping station is approximately 1,500,000 gallons. The average daily consumption of the city for 1915 was 5,500,000 gallons. Most of the isolated wells are equipped with air-lift pumping systems; after the water has reached the surface it is repumped into the mains.

There are other deep wells in the city, as at the Citizens Brewery, Sehring Brewery, State Penitentiary, and the Illinois Steel Mills. Likewise there is a 1,565-foot well at Dellwood Park, a little over a mile north of Joliet.

Some small wells as those at the high school and at the courthouse, penetrate only the St. Peter sandstone. Nearly all the factories have shallow rock wells, which do not yield a large amount.

There has been a lowering of the artesian static head in Joliet as in other parts of northeastern Illinois. The only static head of the St. Peter water obtained in the city was at the high school. The water level in 1913 at rest was reported to be 148 feet below the surface or at an altitude of about 400 feet. The pumping effects are not known, but the working barrel at present is at a depth of 233 feet. The level in the village well at Rockdale, about two and a half miles southwest of the high school, was 72 feet below the surface or at an elevation of 476 feet during September, 1915. The St. Peter wells at the Joliet Water Works flowed up to 1900 at least.

The "Potsdam" static head in 1899 was about 40 feet above the surface or at an elevation of 575 feet.[1] The quantity obtained by the natural flow was not sufficient so that the wells were pumped; the level was then lowered to 70 feet below the surface. In 1907, at the time the first isolated city well was drilled, the water level at rest was 8 feet below the surface or at an approximate altitude of 527 feet. The normal level in this well during October, 1913, was reported as 58 feet, but pumping at the rate of 1,000,000 gallons per day lowered it to 140 feet. The level in the Van Buren Street well was 63 feet below the surface or at an altitude of 468 feet, but dropped to 240 feet when pumping at the rate of 650,000 gallons per day. At the Desplaines Street well, the level in 1913 was 64 feet, or at an approximate elevation of 464 feet, but receded to 180 feet when the pumpage was 650,000 gallons per day. The static head on April 19, 1915, in the recently completed Ruby Street well was 160 feet below the surface or at an altitude of about 384 feet. This well is cased with 10-inch pipe to a depth of 1,207 feet. The water level is very low in comparison with those of the other wells when at rest. However there are two wells about 2,000 feet distant having a combined daily pumpage of at least 1,500,000 gallons which very probably affect the level at Ruby Street, as information collected in Chicago indicated that such heavy pumpage may affect wells at an even greater distance. The water level in the well at the Citizens Brewery on September 25, 1915, was 85 feet below the surface or at an altitude of 457± feet after the well had been shut down for 5 hours; the normal rate of pumping is about 50 gallons per minute.

The analyses appended indicate that the water from the "Potsdam" sandstone is very moderately mineralized for deep-well waters. That the deep wells at the Citizens Brewery and at the Sehring Brewery furnish much harder waters than do the city wells and the one at the high school is to be explained by the fact that the brewery wells are not cased to keep out the Niagaran limestone water which is hard at this locality and contains considerable scale-forming solids, as indicated by the analyses of the Niagaran well waters at the Moore Stone Company and the Porter Brewery. Particularly if the well is pumped at a rate not much greater than 75 gallons per minute, the final water obtained will resemble that from the Niagaran limestone more strongly than that from the deeper strata. The St. Peter water in this vicinity is also of rather low mineral content according to analyses of the waters from the wells at the Joliet High School and the Rockdale village well, both of which have sufficient casing to shut out the waters from the Niagaran limestone.

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[1] Leverett, F., The Illinois glacial lobe: U. S. Geol. Survey Monograph 38, p. 649, 1899.

The waters from strata at a depth of 2,000 feet or more will probably be highly mineralized. A 2,000-foot well at the Steel Mills is reported to yield water of a high mineral content. It might be here mentioned that the 1,922-foot well at Lockport, less than four miles north of Joliet, encountered salt water.

The temperature of the water from the 1,575-foot Desplaines Street well was 58.5° F. at the curb. The water from the 881-foot well at the high school was 55.8° F., delivered from the deep-well pump. The waters from wells a few hundred feet in depth varied in temperature from 53° to 54.5° F.

Log of the Joliet City Well, Canal and Division Sts.

Elevation—552 feet

Generalized section[a]

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Sand and gravel	3½	3½
Silurian system		
Niagaran limestone		
Dolomite, gray, fine grained	226½	230
Ordovician system		
Maquoketa shale		
Shale, dark gray	90	320
Galena-Platteville limestone		
Dolomite, light gray and gray, fine grained	300	620
St. Peter sandstone		
Sandstone	200	820
Prairie du Chien group		
Dolomite, gray, subcrystalline	225	1045
Dolomite, gray, in some instances contains sand grains	180	1225
Dolomite, sandy, contains numerous specks of dark mineral, glauconite	30	1255
Sandstone, dolomitic, greenish gray, numerous specks of a black mineral glauconite	25	1280
Dolomite, gray, subcrystalline, contains some quartz sand	50	1330
Cambrian system		
"Potsdam" group		
Sandstone, gray, rounded grains	240	1570

[a] The detailed log of this well compiled from study of samples is to be found in the Survey files if desired for reference.

LOCKPORT

The city of Lockport had a well drilled in 1895 to a depth of 1,922 feet, but salt water was obtained from the deeper strata, so it was plugged at 1,650 feet.

The driller's log of this well follows:

Driller's log of the Lockport city well

Elevation—568+ feet

(Authority, J. P. Miller Artesian Well Company, Chicago, Illinois)

Description of strata	Thickness *Feet*	Depth *Feet*
Soil, sand, and gravel	3	3
Limestone	200	203
Shale	87	290
Limestone	245	535
Limestone, brown, hard	95	630
Sandstone (*St. Peter*)	230	860
Shale and red marl, "caves"	60	920
Limestone, sandy	280	1200
Limestone, hard	75	1275
Limestone, sandy; and green shale	35	1310
Sandstone "Potsdam"	220	1530
Shale, sandy	110	1640
Marl, red	80	1720
Shale	150	1870
Sandstone	52	1922

The original flow was 275 gallons per minute, but the static head lowered gradually until in 1915 it was 14 feet below the surface, or at an altitude of about 554 feet. The water level drops to 60 feet when pumping at the rate of 150 gallons per minute. The diameter of the well is 10 inches at the surface and about 6 inches at the bottom.

The water has a high mineral content consisting of a considerable amount of alkali chlorides, as well as the salts of calcium. The amount of mineral matter is greater than that present in the waters from wells at a similar depth at Joliet; it may be that some of the water from the lower depths is able to get by the plug at 1,650 feet.

MOKENA

The village is situated near the crest of the Valparaiso morainic system, and consequently the mantle of drift is very heavy. Some wells 125 to 150 feet in depth do not penetrate the bed rock or Niagaran limestone. There are many dug wells which vary in depth from 15 to 40 feet.

The village water supply is furnished by a drilled well 139 feet deep and cased the entire distance. There is a 4-foot screen at the bottom. The water level and effects of pumping are not known, but the working barrel is placed at a depth of 129 feet.

There is no record of the amount pumped, but there are only 17 services, of which the largest is the Rock Island Railroad, with a con-

sumption of 12,000 gallons per day. The water is hard and contains a considerable amount of scale-forming solids.

MONEE

The village is situated near the crest of the Valparaiso moraine. Its altitude of 803 feet makes it one of the highest points in the county.

The public water supply is furnished by two wells that penetrate the Niagaran limestone. The old well, drilled in 1897, is 166 feet in depth and is cased to bed rock with 90 feet of 6-inch pipe. Well No. 2, drilled in 1913, is about the same depth and is cased with 10-inch pipe to bed rock at 90 feet. The wells are only 20 feet apart. The water level at rest is 72 feet below the surface in both wells. The old well will deliver 35 gallons per minute continuously; the working barrel is at a depth of 85 feet. The working barrel in well No. 2 is at a depth of 95 feet; the pump will draw air in about 1.5 hours when operating at the rate of 165 gallons per minute, this is when the other well is also delivering 35 gallons per minute.

The analyses of the waters are given. There is a high content of scale-forming solids in each of the waters and they would not be adaptable for boiler use without considerable softening.

PEOTONE

The village is located in the southern half of the Valparaiso morainic system and is underlain by a heavy drift deposit consisting for the most part of about 100 feet of sandy clay above a stratum of sand and gravel which yields a strong supply of water.

The public water supply is furnished by a 10-inch well 135 feet deep, which obtains its yield from the bed of sand and gravel. The casing extends to the water-bearing formation. The water level at rest is 25 feet below the surface; no pumping tests have been made, but during a fire the well delivered 210 gallons per minute for 4 hours. The average daily pumpage is about 40,000 gallons.

The analysis indicates a rather hard water that does not differ greatly from that obtained from other wells of like depth in this area.

PLAINFIELD

The village of Plainfield completed a 1,302-foot well in 1915. The chief water-bearing strata are the St. Peter sandstone and Prairie du Chien limestone. The water level at rest is about 55 feet below the surface or at an altitude of approximately 557 feet. The well has a surface diameter of 12 inches and is completed at about 8 inches. The pumpage is at the rate of 175 gallons per minute, but the recession is not known. The cost of well and pump was about $6,000.

This new well supplants an old Niagaran limestone well that is kept in order only for emergencies. An analysis of the water from the old well is appended in the absence of one from the new well.

ROCKDALE

The village of Rockdale is situated just outside the southwest corner of the corporate limits of Joliet. The municipal water supply is furnished by a 662-foot St. Peter well, cased to a depth of 320 feet with 12-inch pipe; the bottom diameter is 8 inches. The pumping equipment is a double-acting deep-well pump, and the yield is about 160 gallons per minute. In September, 1915, the water level was 72 feet below the surface or at an elevation of 476 feet; the effects of pumping are not known.

The appended analysis indicates a water that is practically identical with that from the well at the Joliet high school. There is enough mineral matter so that some soft scale would be formed if it were used untreated in boilers. As compared with the water from the 640-foot well at the American Can Company, the latter is considerably harder because not all of the Niagaran limestone water has been cased off.

STEGER

The city is located near the northern border of the Valparaiso moraine and at a lower elevation than the region to the south and west. This higher, drift-covered area constitutes a favorable collecting area, so that wells to the north, at a lower elevation, yield large supplies.

The municipal supply is furnished by a 318-foot well which penetrates the Niagaran limestone for 224 feet. The well is cased with 12-inch pipe to a depth of 147 feet where the working barrel of the pump is also placed. No pumping tests have been made, but the pump operates for 4 or 5 hours per day at the rate of over 300 gallons per minute; the recession during pumping has not been determined.

There are two similar wells at the Steger piano factory. These wells are so connected with the city supply that the combined pumpage is available for fire protection. The analysis of the water shows a considerable amount of dissolved mineral matter, chiefly the bicarbonates of calcium and magnesium.

WILMINGTON

The village is situated on the banks of the Kankakee at a low elevation with respect to the surrounding country. The drift probably does not average over 25 feet thick; in fact, the Niagaran limestone outcrops along Kankakee River and Forked Creek.

The waterworks is only for fire protection and obtains its supply from the Kankakee. It was understood that a large St. Peter well was

to be drilled in 1916. The dug wells, 15 to 30 feet deep, yield sufficient water for domestic purposes. Numerous springs also occur along Forked Creek and the river. Two flowing wells about 800 feet in depth have been reported. The water-bearing formation is probably the St. Peter sandstone, but the wells are very old and little is known concerning them.

WINNEBAGO COUNTY

Physiography

Winnebago County is situated along the northern border of the State, about midway of its width; Boone County adjoins it on the east, Lee County on the south, and Stephenson County on the west. The total area is 529 square miles.

The drift deposit covering this county is not heavy except in a few places. The original topography has therefore not been greatly modified. The land as a whole is gently rolling, although the numerous streams have cut it up considerably. Prominent bluffs have been developed in many places along Rock River. Rarely are any marshes or undrained areas found, which renders the topography strikingly different from that of the heavier drift-covered counties to the east.

The drainage of the county is effected by Rock River and its tributaries. This stream enters the county in the northeastern township and flows southward across the eastern part. It differs from most Illinois rivers in that the waters are clear and swift flowing. Water power is developed in a number of places along this stream. Pecatonica River is one of the important tributaries and drains the northwestern part of the area. Kishwaukee River drains the southeastern corner.

Geology

The drift mantle is not heavy except in the pre-glacial valleys. In the western portion of the county the deposit is very thin; the rock is found on the uplands within 15 or 20 feet of the surface and in many places it outcrops. A loess-like deposit of silt covers much of this portion of the county. East of Rock River the drift is much heavier, probably averaging at least 100 feet thick. Along the pre-glacial valley of Rock River the drift attains thicknesses of 300 feet. Borings show that the rock floor of the pre-glacial valley is 250 to 300 feet below the present river bed.[1] The drift in the Rockford city well No. 8 was 248 feet thick and was underlain by the St. Peter sandstone, although the Galena-Platteville formation outcrops in the city along Rock River.

[1] Leverett, F., The Illinois glacial lobe: U. S. Geol. Survey Monograph 38, 1899.

A knowledge of the rock formations has been obtained from well logs at Rockford from the examination of the drillings of a 1,500-foot well and also through previous work of the Illinois State Geological Survey. The bed rock formation of the greater part of the county is the Galena-Platteville formation. The upper division, or the Galena limestone, is the underlying formation over two-thirds of the county. The area underlain by this formation is given by James Shaw[1] as follows:

"An imaginary line entering the county about the southeast corner of the township of Roscoe, drawn thence in a southeast course until Rock River was reached; thence extended round in a slight bend toward the northwest, until within a short distance of the Pecatonica River, at a point about four miles west of its mouth; thence meandering along the Pecatonica from one to two miles south of the thread of that stream, until the western boundary of the county was reached; thence starting south and keeping around the boundary line to the place of beginning, and embracing about two-thirds of the county, would indicate the superficial extent of this division, to which would have to be added a narrow strip, extending from the village of Pecatonica, up toward and nearly to the northwestern corner of the county."

A number of quarries are worked in this area and the rock is seen to be a heavy-bedded, yellowish to cream-colored dolomitic limestone.

The lower division of Galena-Platteville limestone is called by Shaw the "Blue Limestone" and is described by him as a thin-bedded, bluish-gray limestone having a few shaly partings. The Platteville limestone is the bed rock formation over practically all of that part of the county in which the Galena is absent.

It is also known that small outcrops of St. Peter sandstone occur in a few places along Rock River and other streams in the northern part of the county.

As revealed by the Rockford drilling, the St. Peter sandstone has its customary thickness, but the underlying Prairie du Chien limestone is not over 200 feet thick. Even this amount is only obtained by including the lower 70 feet of reddish-brown, glauconiferous, dolomitic sandstone and shale, which may represent the Madison-Mendota horizon. Below these strata there is a great series of sandstones which range from fine to coarse grained. As in the section at Belvidere.

Underground Waters

SOURCES

Practically all the data concerning the static head of the waters from the different horizons have been obtained at Rockford. At the Rockford water-works station there has been a recession of approximately 38 feet

[1] Shaw, James, Geol. Survey of Illinois, vol. V, p. 86, 1873.

in the "Potsdam" water level since the first well was drilled in 1885. The present static head at this water works is about 5 feet below the surface. This location is at a low elevation, but it is still probable that flowing wells may be obtained at low elevations along Rock River, provided they are a few miles from the Rockford water works.

A few flowing wells from the St. Peter sandstone still exist, but the level is usually a few feet below the surface. The head from the "Potsdam" sandstone is from 10 to 20 feet greater than that of the St. Peter sandstone.

CHEMICAL CHARACTER

The waters from all the different horizons are moderately but not excessively mineralized. In general it might be said that the waters from wells 50 feet or so in depth are less mineralized than those of greater depths. The waters from these shallow horizons, however, are not always abundant and they may also be subject to surface contamination.

LOCAL SUPPLIES

PECATONICA

The drift in this vicinity is only a few feet thick so that practically all wells penetrate rock. Private wells are from 80 to 125 feet in depth. The village water supply is obtained from a well 12 feet in diameter and 20 feet deep. The greater part of the depth is in limestone. The well is located in a valley in the south part of the village; as this is at a low elevation the ground water level is high. Most of the water enters the well on the north side through the fissured limestone. The water level at rest is within 6 or 7 feet of the surface. The daily consumption is about 20,000 or 25,000 gallons which is pumped in 2½ to 3 hours. The water is moderately mineralized and would form some scale if used untreated in boilers.

ROCKFORD

The geological succession in the city is shown by the log of well No. 8, which was compiled from a study of the drillings. Another well has been drilled to a depth of 1,981 feet, but only the driller's log was kept. In the lower part of this well 275 feet of red shale was reported to be underlain by 171 feet of white sandstone, in which the drilling was stopped.

Some of the wells at the pumping station show as much as 50 feet of the limestone before the St. Peter sandstone is struck. This is to be expected, as this limestone outcrops along Rock River. However, the limestone was not found in wells No. 7 and 8, but the drift was much

thicker. The St. Peter sandstone has a considerable thickness, but the Prairie du Chien limestone is only 100 feet thick if the lower 70 feet of reddish dolomitic sandstone and shale that probably represents the Madison and Mendota formations is excluded. The great series of sandstones at the lower horizons are the important water-bearing formations.

Log of Rockford City Well No. 8
Elevation—728 feet
Generalized section[a]

Description of strata	Thickness *Feet*	Depth *Feet*
Quaternary system		
Pleistocene and Recent		
Not represented in samples, probably sand and gravel..	70	70
Sand, gravel, and pebbles, probably river wash..........	178	248
Ordovician system		
St. Peter Sandstone		
Sand, colorless, well rounded..........................	145	393
Prairie du Chien group		
Chert, white..	37	430
Dolomite, gray, crystalline............................	70	500
Sandstone, dolomitic, reddish brown containing some glauconite sand grains...............................	50	550
Shale, reddish brown, sandy and dolomitic..............	20	570
Cambrian system		
"Potsdam" group		
Sandstone, well rounded, colorless quartz grains.......	150	720
Shale, red and green...................................	40	760
Shale, green, slightly sandy and dolomitic...............	30	790
Sandstone, subangular to well rounded, colorless, or light yellow, quartz grains.........................	540	1330
Sandstone, chocolate in color due to cementing material, varying in size from a fine powder to a coarse sand....	170	1500

[a] The detailed log of this well compiled from study of samples is to be found in the Survey files if desired for reference.

The first municipal water system was constructed during 1874 and 1875 and the source was a number of springs along Rock River in the north part of the city. In a few years it was found that this supply was inadequate, and at times of heavy consumption it was necessary to draw water from Rock River. In 1885 on the advice of Prof. T. C. Chamberlin the first artesian well was sunk to a depth of 1,530 feet. A flowing well was obtained with a head of approximately 33 feet above the surface or at an elevation of about 745 feet. Additional deep wells were drilled from 1885 to 1888 at the rate of one well per year. These five flowing wells ranging in depth from 1,300 to 2,000 feet constituted the source of the city's supply until 1891. It was again found necessary

to increase the supply, and this was done by drilling four wells which penetrated the St. Peter sandstone. Still further changes were made at various times, such as the building of storage reservoirs. In 1895 pumping equipment was installed for the flowing "Potsdam" wells that had not previously been pumped.

A contract was made in 1896 with Mr. Daniel W. Mead for the construction of a shaft and tunnel system. On the completion of this project three "Potsdam" wells and five St. Peter wells were tapped at a low level and the water permitted to flow to a central shaft. This shaft is 95 feet deep and contains at the bottom three pumps of a centrifugal type. On a 24-hour test made by the city in 1898 the yeild was 6,800,000 gallons. In 1910 it was found that the amount of water obtained from the shaft and tunnel system had decreased nearly one-half, and as the population had greatly increased, it was necessary to obtain a greater supply. A commission consisting of J. W. Alvord, D. W. Mead, and D. H. Maury was appointed to investigate the possibility of increasing the water supply. This commission outlined six plans. The city accepted the one which provided for the construction of large wells at a considerable distance from one another. At the present time two of these wells, Nos. 7 and 8, have been sunk, the former approximately 1¾ miles southeast of the old pumping station, and the latter about 2½ miles north of well No. 7. One of the wells was completed in 1913 and has therefore been in operation nearly three years. The results obtained have been very satisfactory. The three "Potsdam" wells of the shaft and tunnel system range in depth from 1,300 to 1,530 feet, and the five connected St. Peter wells average about 450 feet in depth. These wells are reported to be cased with 150 feet of 8-inch pipe which penetrates bed rock.

Well No. 7, which is 1,503 feet in depth and penetrates the "Potsdam", is cased with 250 feet of 18-inch pipe, below which there is also 200 feet of 12-inch pipe embedded in limestone which excludes all water from the St. Peter sandstone. The drilling costs are given as follows:

18-inch casing per lineal foot	$16.00
12-inch casing per lineal foot	6.25
12-inch uncased per lineal foot	3.00

This would give a total cost of $8,409. The well was drilled by the Cater Contracting Company of Chicago and completed in February, 1913. The pumping equipment was furnished by the American Well Works and is a 17-inch, 6-stage combination deep-well and pressure pump, being a 4-stage, turbine type of pump located 108 feet in the well, with a 2-stage centrifugal type of pump at the top of the casing. The well is covered by a small, brick pump house which protects the motor and

other surface equipment. The entire cost of installation was approximately \$20,000, which included ground, well, pump house, motor, and automatic starting apparatus. The cost of pumping, which includes interest and depreciation on equipment, is reported as 2 cents per 1,000 gallons delivered to the mains. This well delivers 1,400 gallons per minute.

Well No. 8 was drilled in 1914-15 but the pumping equipment has not yet been installed. The cost of drilling was as follows:

22-inch casing per lineal foot	\$24.45
12-inch casing per lineal foot	6.75
12-inch uncased per lineal foot	2.50

However, a lump bid of \$8,990 was made for drilling to a depth of 1,500 feet. The contractors for each of these wells furnished the coal for heating their boilers.

The water level at rest in well No. 7 is 108 feet above city datum; the water level when delivering 1,400 gallons per minute is 42 feet, or a lowering of 66 feet. This static head is higher than that at the pumping station, which is probably due to several causes. The well is over a mile distant from the old pumping station, is new and therefore clogging is absent, and the large diameter reduces the pipe friction. Well No. 8 at rest has a water level of 120 feet above the city datum. As the pumping equipment has not yet been installed it is not possible to give the effects of pumping.

In many parts of Rockford the St. Peter sandstone either directly underlies the drift, or is found just below the thin Galena-Platteville formation. There is consequently some variation in the St. Peter water level but it is usually within a few feet of the surface except in the higher portions of the city. Rarely does a flowing well occur. The St. Peter water level at the Graham Distillery was 11 feet below the surface in March, 1914; the surface elevation is 102+ feet, city datum or 707 feet above sea level. In the well owned by the Chicago, Milwaukee and St. Paul Railway Company the St. Peter water level was 12 feet below the surface in 1913, whereas the ground water was only 8 feet.

At the time the first "Potsdam" well in Rockford was drilled in 1885, the head was approximately 33 feet above the surface. The lowering of the water table since that time has not been excessive and is not at all comparable with that in the Chicago area. The following data concerning the water levels at various times have been obtained:

Static head of "Potsdam" water table at Rockford

Well No.	Surface altitude above city datum[a]	Year drilled	Depth	Altitude of static head above city datum[a]			
				Original	Nov. 1891	1910	1915
	Feet		*Feet*				
1	107±	1885	1,530	135.9	113.0	102±	102±
2	107±	1886	1,320	116.7	112.4	102±	102±
3	107±	1886	1,981	120.8	118.5	102±	102±
4	107±	1887	1,300	116.0	114.4	102±	102±
5	107±	1888	1,379	127.7	118.7	102±	102±
7	130.3	1913	1,503	.....	.....	.....	108
8	122.5	1915	1,500	120	.....	.....	120

[a] City datum is 605 feet above sea level.

A series of very accurate tests was made upon these wells in August, 1910, and it was found that when the wells were being pumped at the rate of 3,600,000 gallons per day, the recession in the water level was approximately 75 feet. The rising curves made at that time show that 60 feet of the recovery was made within 15 minutes after pumping had ceased. The remainder of the recovery required over 4 hours. Tests were made by Mr. O. E. Bulkeley of the Rockford Engineering Department, January 24, 1914, in order to determine the water levels. The wells selected were Nos. 2 and 4; the latter is connected with the shaft and tunnel system and No. 2 is only a few hundred feet distant. The wells were shut down for nearly 5 hours and measurements made at frequent intervals during this period. The rising curves obtained are similar to those of 1910, which place the static head at approximately 102 feet above city datum; this is for the wells at the pumping station.

It was found that the specific capacity, or the yield under one foot head, of the "Potsdam" wells had decreased greatly since 1891. This is shown by the following table by Prof. C. S. Slichter contained in the 1910 report of the Rockford water commission.

Professor Slichter does not consider that the reduction in specific capacity is entirely due to the mechanical clogging of the water-bearing sandstone in the vicinity of the wells. He believes that much of the clogging is because of the growth of low forms of plant life in the pores of the rock in the walls of the well, supported by the carbon dioxide liberated as a result of the reduction in pressure.

Specific capacity of Rockford wells

Date	Wells	Head	Flow per 24 hours	Specific capacity per 24 hours
	No.	*Feet*	*Gallons*	*Gallons*
1891	1	8.05–0.28[a]	143,654	18,600
	4	11.64–1.00[a]	291,711	27,600
	5	8.29–2.70[a]	232,818	30,600
				76,800
1898	1, 4, and 6	98.5[b]	6,714,000[b]	......
		98.5–10[a, c]	4,714,000[c]	60,000[c]
1910	1, 4, and 6	76.5[b]	3,670,000[b]	......
		76.5–7.5[a, c]	2,670,000[c]	38,600

[a] The amounts deducted from heads are the approximate losses of head due to pipe friction.

[b] Including St. Peter sandstone. [c] Deducting for St. Peter sandstone.

APPENDIX

Mineral and Boiler Analyses of The Artesian Waters of Northeastern Illinois

TABLE I.—*Mineral analyses of underground*

County	Boone	Cook	Cook	Cook
Town	Belvidere	Barrington (Waterworks)	Bellewood (Waterworks)	Chicago (Armour powerhouse, U. S. yards)
Owner	......	Village	Village	Armour & Co.
Depth of well....feet	1,800	315	1,538	1,581
Depth of casing....feet	......	200	87	To bed rock
Rate of pumping.. gals. per min.	......	400	200	1,000
Date sample was collected	Oct. 21, '13	Aug. 24, '14	July 7, '14	July 20, '14
				Determinations made
Potassium	3.3	2.7	4.7	42.5
Sodium	6.3	21.6	39.8	697.
Ammonium	.2	.8	.5	2.1
Magnesium	45.5	39.9	50.1	83.1
Calcium	110.8	51.7	61.9	375.3
Iron	.07	.4	1.	1.5
Alumina	.2	1.7	2.6	4.
Nitrites	.3	.0	.0	.0
Nitrates	9.5	2.7	.0	.7
Chlorine	24.	......	6.	1500.
Sulphate	85.3	79.3	174.2	413.9
Silica	12.1	37.9	19.	19.5
Hydrogen sulphide	......	......	......	.42
Manganese	......	......	......	......
Bases	......	.6	1.6	1.
				Hypothetical combinations
Potassium nitrite	.5	......	......	......
Potassium nitrate	8.	4.4	......	1.1
Potassium chloride	......	......	9.	80.2
Potassium sulphate	......	......	......	......
Sodium nitrate	6.3	3.8	......	......
Sodium chloride	11.7	......	2.8	1769.
Sodium sulphate	......	66.6	119.3	......
Sodium carbonate	......	......	......	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	.6	......	......	6.2
Ammonium sulphate	......	2.9	1.8	......
Ammonium carbonate	......	......	......	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	22.1	......	......	325.
Magnesium sulphate	106.9	37.7	115.7	......
Magnesium carbonate	63.3	111.9	92.5	......
Calcium chloride	......	......	......	224.9
Calcium sulphate	......	......	......	586.7
Calcium carbonate	276.5	129.	154.5	303.3
Iron carbonate	.1	.8	2.1	3.1
Alumina	.2	1.7	2.6	4.
Silica	12.1	37.9	19.	19.5
Bases	.0	.6	1.6	1.
Total	508.3	397.3	520.9	3324.
				Hypothetical combinations
Potassium nitrite	.03	......	......	......
Potassium nitrate	.46	.26	......	.06
Potassium chloride	......	......	.52	4.68
Potassium sulphate	......	.22	......	......
Sodium nitrate	.37	......	......	......
Sodium chloride	.68	......	.16	103.18
Sodium sulphate	......	3.88	6.96	......
Sodium carbonate	......	......	......	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	.03	......	......	.36
Ammonium sulphate	......	.17	.1	......
Ammonium carbonate	......	......	......	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	1.29	......	......	18.96
Magnesium sulphate	6.23	2.2	6.75	......
Magnesium carbonate	3.69	6.53	5.39	......
Calcium chloride	......	......	......	13.12
Calcium sulphate	......	......	......	34.22
Calcium carbonate	16.12	7.52	9.01	17.69
Iron carbonate	.01	.05	.12	.18
Alumina	.01	.1	.15	.23
Silica	.7	2.21	1.11	1.14
Bases	.0	.03	.09	.06
Total	29.62	23.17	30.36	193.88

waters in northeastern Illinois

Cook Chicago (Packers Ave., Union S. Yards) Armour & Co.	Cook Chicago (Oakley St. & 48th Ave.) Illinois Vinegar Works	Cook Chicago (Union Stock Yards. Oleo. house) Morris & Co.	Cook Chicago (Union Stock Yards) Sulzberger Sons & Co., well No. 2	Cook Chicago (Arthington & Homan Ave.) Sears Roebuck & Co.	Cook Chicago (Arthington & Homan Ave.) Sears Roebuck & Co.	Chemical formula
1,600	1,942	2,300	1,620	1,623	1,868	
70	56	To bed rock	64	92	853	
1,400	275	250	635	340	530	
July 16, '14	June 26, '15	Aug. 31, '14	Aug. 31, '14	Oct. 7, '15	Oct. 7, '15	
(parts per million)						
25.2	20.	70.9	21.3	25.4	33.6	K
220.8	320.3	1232.	138.8	185.2	330.5	Na
.8	1.3	4.1	7.2	.6	6	NH_4
48.9	74.4	122.5	42.	25.4	29.	Mg
213.3	45.2	543.2	130.7	143.8	163.8	Ca
1.3	.4	3.6	.4	.5	.3	Fe
2.	3.4	4.9	4.2	2.5	6.4	Al_2O_3
.0	.0	.0	.0	.0	.0	NO_2
1.1	2.1	1.8	1.8	1.2	1.2	NO_3
280.	405.	2900.	135.	255.	490.	Cl
547.2	304.7	314.8	374.8	324.9	329.2	SO_4
16.8	10.4	20.	15.2	12.8	10.	SiO_2
.38	......	......	......	......	......	H_2S
......	......	.08	......	.0	.0	Mn
.0	2.4	1.	.8	.0	.0	Bases
(parts per million)						
......	......	......	......	......	......	KNO_3
1.8	3.4	2.9	2.9	2.	2.	KCl
46.7	35.6	133.	38.5	46.9	62.5	K_2SO_4
......	......	......	......	......	......	$NaNO_3$
......	......	......	......	......	......	NaCl
426.1	640.4	3126.8	193.	384.	759.6	Na_2SO_4
166.2	209.7	......	191.2	104.5	96.2	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
......	......	......	......	......	......	NH_4Cl
......	......	12.1	......	......	......	$(NH_4)_2SO_4$
2.9	4.8	......	26.3	2.2	2.2	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
......	......	......	......	......	......	$MgCl_2$
......	......	479.	......	......	......	$MgSO_4$
241.7	200.	......	207.6	125.6	143.4	$MgCO_3$
......	117.4	......	......	......	......	$CaCl_2$
......	......	904.1	......	......	......	$CaSO_4$
343.	......	446.2	86.3	216.0	210.3	$CaCO_3$
252.	112.8	212.7	262.8	200.4	255.4	$FeCO_3$
2.7	.8	7.5	.8	1.	.6	Al_2O_3
2.	3.4	4.9	4.2	2.5	6.4	SiO_2
16.8	10.4	20.	15.2	12.8	10.	Bases
2.4	2.4	1.	.8	......	......	
1504.4	1341.1	5350.2	1029.6	1097.9	1548.6	Total
(grains per U. S. gallon)						
......	......	......	......	.12	......	KNO_2
.1	.2	.17	.17	2.74	.11	KNO_3
2.72	2.08	7.76	2.25	......	3.63	KCl
......	......	......	......	......	......	K_2SO_4
......	......	......	......	22.40	......	$NaNO_3$
24.85	37.35	182.39	11.26	6.09	44.31	NaCl
9.69	12.23	......	11.15	......	5.60	Na_2SO_4
......	......	......	......	......	......	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
......	......	.71	......		......	NH_4Cl
.17	.28	......	1.53	.13	.13	$(NH_4)_2SO_4$
......	......	......	......	......	......	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
......	......	27.93	......	......	......	$MgCl_2$
14.1	11.67	......	12.11	7.33	8.36	$MgSO_4$
......	6.84	......	......	......	......	$MgCO_3$
......	......	52.74	......	......	......	$CaCl_2$
20.01	......	26.03	5.03	12.60	12.26	$CaSO_4$
14.70	6.58	12.41	15.33	11.70	14.90	$CaCO_3$
.16	.05	.44	.05	.06	.03	$FeCO_3$
.12	.20	.29	.24	.15	.37	Al_2O_3
.98	.61	1.17	.89	.75	.58	SiO_2
.14	.14	.06	.05	......	......	Bases
87.74	78.23	312.10	60.06	64.07	90.28	Total

TABLE I.—*Mineral analyses of underground*

County	Cook	Cook	Cook	Cook
Town	Forest Park (Jackson Blvd. & Lehmer St.)	Matteson (Waterworks)	Riverdale (Waterworks)	Proviso Township (SE. ¼ NW. ¼ sec. 5)
Owner	City	Village	Village	Chicago North Western R. R. well No. 5
Depth of well . . . feet	2,012	282	434	1,841
Depth of casing . . . feet	90±	To bed rock	50	1,725
Rate of pumping . . gals. per min.	765	200	125	90
Date sample was collected	June 28, '15	Oct. 27, '14	June 30, '15	June 30, '15

Determinations made

Potassium	15.	6.6	13.2	16.
Sodium	97.5	34.8	106.1	113.6
Ammonium	.5	.8	.3	.4
Magnesium	33.1	35.9	9.	8.1
Calcium	83.8	123.2	20.2	13.5
Iron	.5	4.0	.3	.3
Alumina	1.1	4.5	1.4	1.
Nitrites	.0	.0	.0	.0
Nitrates	1.1	1.8	1.1	1.1
Chlorine	85.	4.	16.	44.
Sulphate	165.9	219.7	72.9	45.3
Silica	9.2	11.4	11.	10.8
Manganese	......	.04	......	......
Bases	.6	1.6	1.	1.4

Hypothetical combinations

Potassium nitrite	......	......	......	......
Potassium nitrate	1.8	2.9	1.8	1.8
Potassium chloride	27.2	8.4	23.8	29.2
Potassium sulphate	......	2.4	......	......
Potassium carbonate	......	......	......	......
Sodium nitrate	......	......	......	......
Sodium chloride	119.	......	7.8	49.7
Sodium sulphate	156.	107.3	107.9	67.
Sodium carbonate	......	......	156.5	166.4
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	......	......	......
Ammonium sulphate	1.8	2.9	......	......
Ammonium carbonate	......	......	.8	1.1
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	......	......	......
Magnesium sulphate	130.5	18.	......	......
Magnesium carbonate	23.2	67.5	31.2	28.1
Calcium chloride	......	......	......	......
Calcium sulphate	......	......	......	......
Calcium carbonate	209.2	307.5	50.4	78.6
Iron carbonate	1.	8.3	.6	.6
Alumina	1.1	4.5	1.4	1.
Silica	9.2	11.4	11.	10.8
Bases	.6	1.6	1.	1.4
Total	680.6	704.7	394.2	435.7

Hypothetical combinations

Potassium nitrite	......	......	......	......
Potassium nitrate	.10	.17	.10	.10
Potassium chloride	1.59	.49	1.39	1.70
Potassium sulphate	......	.14	......	......
Potassium carbonate	......	......	......	......
Sodium nitrate	......	......	......	......
Sodium chloride	6.94	......	.45	2.90
Sodium sulphate	9.10	6.26	6.29	3.91
Sodium carbonate	......	......	9.13	9.71
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	......	......	......
Ammonium sulphate	.10	.17	......	......
Ammonium carbonate	......	......	.05	.06
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	......	......	......
Magnesium sulphate	7.61	10.50	......	......
Magnesium carbonate	1.35	3.94	1.82	1.64
Calcium chloride	......	......	......	......
Calcium sulphate	......	......	......	......
Calcium carbonate	12.20	17.94	2.94	4.58
Iron carbonate	.06	.48	.03	.03
Alumina	.06	.26	.08	.06
Silica	.54	.66	.64	.63
Bases	.03	.09	.06	.08
Total	39.68	41.10	22.98	25.40

waters in northeastern Illinois—Continued

De Kalb De Kalb (Waterworks) City	De Kalb Genoa (Waterworks) Village	De Kalb Hinckley (Waterworks) Village	Dupage Glen Ellyn (Waterworks) Village	Dupage Naperville (Waterworks) City	Dupage West Chicago (Waterworks) City	Chemical formula
......	1,500	708	310	1,375	322	
......	75	100	114	14	90	
......	200	200	275	300	200	
Dec. 21, '14	Oct. 24, '13	May 15, '14	Aug. 5, '14	June 4, '15	Nov. 12, '14	
(parts per million)						
12.2	6.2	3.	4.5	9.6	4.3	K
15.9	5.6	21.8	58.1	20.9	24.7	Na
.5	.4	1.4	.5	.1	.5	NH_4
3.3	33.8	38.5	30.6	44.2	37.4	Mg
75.3	65.6	52.	62.	84.6	66.6	Ca
.1	.0	.7	.4	.1	.8	Fe
1.1	.6	2.1	1.7	1.3	2.1	Al_2O_3
.0	.0	.0	.0	.1	.0	NO_2
.2	.0	1.8	.0	8.8	.0	NO_3
1.	1.	8.	1.	20.	13.	Cl
.0	4.4	1.8	85.6	121.6	62.3	SO_4
33.4	18.4	18.	21.5	7.8	14.1	SiO_2
.0	......	......	......	.00	......	Mn
.0	.6	.9	.7	2.	3.4	Bases
(parts per million)						
......	......	......	......	......	......	KNO_2
.3	......	2.9	......	14.3	......	KNO_3
2.	2.1	3.6	8.6	9.7	8.2	KCl
......	8.	......	......	......	......	K_2SO_4
19.4	2.6	......	......	......	......	K_2CO_3
......	......	......	......	......	......	$NaNO_3$
......	......	10.4	9.7	25.4	15.	NaCl
......	......	2.7	126.6	33.6	58.	Na_2SO_4
36.6	12.9	38.7	30.6	......	......	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
......	......	......	......	......	......	NH_4Cl
......	......	......	......	.3	1.8	$(NH_4)_2SO_4$
......	1.1	3.7	1.3	......	......	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
......	......	......	......	......	......	$MgCl_2$
......	......	......	......	123.8	27.3	$MgSO_4$
11.4	124.	133.3	106.	66.4	110.4	$MgCO_3$
......	......	......	......	......	......	$CaCl_2$
......	......	......	......	......	......	$CaSO_4$
187.9	163.8	129.8	154.8	211.2	166.2	$CaCO_3$
.2	......	1.5	.8	.2	1.6	$FeCO_3$
1.1	.6	2.1	1.7	1.3	2.1	Al_2O_3
33.4	18.4	18.	21.5	7.8	14.1	SiO_2
2.3	.6	.9	.7	2.	3.4	Bases
294.6	334.1	347.6	462.3	496.	408.1	Total
(grains per U. S. gallon)						
......	......	......	......	......	......	KNO_2
.02	......	.17	......	.83	......	KNO_3
.11	.12	.21	.50	.57	.48	KCl
......	.47	......	......	......	......	K_2SO_4
1.13	.15	......	......	......	......	K_2CO_3
......	......	......	......	......	......	$NaNO_3$
......	......	.61	.57	1.48	.87	NaCl
......	......	.16	7.38	1.96	3.38	Na_2SO_4
2.10	.75	2.26	1.78	......	......	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
......	......	......	......	......	......	NH_4Cl
......	......	......	......	.02	.10	$(NH_4)_2SO_4$
......	.06	.22	.08	......	......	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
......	......	......	......	......	......	$MgCl_2$
......	......	......	......	7.22	1.59	$MgSO_4$
.66	7.23	7.77	6.18	3.87	6.43	$MgCO_3$
......	......	......	......	......	......	$CaCl_2$
......	......	......	......	......	......	$CaSO_4$
10.95	9.55	7.57	9.03	12.32	9.69	$CaCO_3$
.01	......	.09	.05	.01	.09	$FeCO_3$
.06	.03	.12	.10	.08	.12	Al_2O_3
1.95	1.07	1.05	1.25	.45	.82	SiO_2
.13	.03	.05	.04	.11	.20	Bases
17.12	19.46	20.28	26.96	28.92	23.77	Total

Table I.—*Mineral analyses of underground*

County	Grundy	Grundy	Grundy	Kane
Town	Coal City	Minooka	Morris	Aurora
	(Waterworks)	(Main St.)	(Waterworks)	(Waterworks) Well No. 3)
Owner	City	City	City	City
Depth of well ... feet	350	2,100	765	2,200
Depth of casing ... feet	285	......	90	250
Rate of pumping..gals. per min.	180	Flows, 40	160	350
Date sample was collected	May 24, '14	Sept. 24, '15	Sept. 22, '15	July 20, '15
				Determinations made
Potassium	28.2	29.6	6.1	14.4
Sodium	242.9	560.	52.	86.2
Ammonium	1.8	.41	......	.4
Magnesium	48.3	19.9	29.5	27.3
Calcium	89.2	88.6	65.5	68.6
Iron	2.8	.3	.1	.4
Alumina	3.8	Trace	.4	.8
Nitrites	.0	.0	.0	.1
Nitrates	.0	.0	6.2	3.
Chlorine	255.	910.	9.	135.
Sulphate	339.7	41.3	53.	36.7
Silica	10.6	10.4	11.	10
Manganese	......	.0	.0	.0
Bases	1.	4.	3.6	.0
				Hypothetical combinations
Potassium nitrite	......	......	......	.2
Potassium nitrate	......	......	......	4.9
Potassium chloride	53.7	56.4	4.2	23.6
Potassium sulphate	......	......	......	......
Sodium nitrate	......	......	10.1	......
Sodium chloride	378.7	1421.2	11.6	183.8
Sodium sulphate	288.9	......	78.4	42.5
Sodium carbonate	......	......	50.6	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	1.2	......	......
Ammonium sulphate	6.6	......	......	1.5
Ammonium carbonate	......	......	......	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	28.5	......	......
Magnesium sulphate	175.1	51.7	......	8.6
Magnesium carbonate	44.7	7.5	102.1	88.6
Calcium chloride	......	......	......	......
Calcium sulphate	......	......	......	......
Calcium carbonate	222.7	221.1	163.5	171.1
Iron carbonate	5.8	.6	.2	.8
Alumina	3.8	trace	.4	.8
Silica	10.6	10.4	11.	10.
Bases	1.	4.	3.6	......
Total	1191.6	1802.6	435.7	536.4
				Hypothetical combinations
Potassium nitrite	......	......	......	.01
Potassium nitrate	......	......	......	.29
Potassium chloride	3.13	3.29	.24	1.38
Potassium sulphate	......	......	......	......
Sodium nitrate	......	......	.59	......
Sodium chloride	22.09	82.90	.68	10.72
Sodium sulphate	16.85	......	4.56	2.48
Sodium carbonate	......	......	2.95	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	.07	......	......
Ammonium sulphate	.38	......	......	.09
Ammonium carbonate	......	......	......	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	1.66	......	......
Magnesium sulphate	10.21	3.00	......	.50
Magnesium carbonate	2.61	.44	5.95	5.17
Calcium chloride	......	......	......	......
Calcium sulphate	......	......	......	......
Calcium carbonate	12.99	12.89	9.54	9.98
Iron carbonate	.34	.03	.01	.05
Alumina	.22	trace	.02	.05
Silica	.62	.61	.64	.58
Bases	.06	.23	.21	......
Total	69.50	105.12	25.39	31.30

waters in northeastern Illinois—Continued

Kane Aurora	Kane Aurora	Kane Aurora	Kane Aurora	Kane Batavia	Kane Montgomery	
(Waterworks) Well No. 5)	(Talma St. well)	(River St. well)	(Philips Park well)	......	(SE. ¼ sec. 32, T. 38 N., R. 8 E.)	Chemical formula
City	City	City	City	City	Magnesia Spring Co.	
2,250	2,185	2,263	2,759	2,000	115	
255	350	255	135	......	......	
650	450	Flows, 150	100	......	Flows, 5	
July 20, '15	July 20, '15	July 20, '15	July 20, '15	Sept. 28, '15	July 20, '15	

(parts per million)

11.	16.	16.6	26.1	1.5	14.9	K
48.1	51.2	134.7	486.2	5.5	157.4	Na
.5	.1	.3	.8	.6	.6	NH_4
24.9	23.3	28.7	62.1	22.4	10.4	Mg
64.5	63.5	82.9	240.5	56.	15.3	Ca
.4	.3	.5	5.	.3	.2	Fe
1.2	.4	1.2	1.6	4.	.9	Al_2O_3
.5	.0	.0	.0	.0	.0	NO_2
3.5	3.5	1.1	1.8	1.2	2.5	NO_3
93.	35.	258.	1075.	10.	1.	Cl
27.2	41.9	29.6	107.1	6.	76.2	SO_4
9.	10.5	12.	11.6	15.6	11.6	SiO_2
.0	.0	.0	.0	.0	.0	Mn
.0	.2	.4	.0	.0	.0	Bases

(parts per million)

.9	......	......	......	......	......	KNO_2
5.7	5.7	1.8	2.9	2.	4.1	KNO_3
16.	26.3	30.3	47.6	1.3	2.1	KCl
......	......	......	......	......	27.2	K_2SO_4
......	......	......	......	......	......	$NaNO_3$
122.1	37.1	341.8	1234.	14.	......	NaCl
......	62.	......	......	......	90.6	Na_2SO_4
......	38.	......	......	......	294.6	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
1.5	......	.9	1.9	1.7	......	NH_4Cl
......	......	......	......	......	......	$(NH_4)_2SO_4$
......	.3	......	......	......	1.6	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
13.9	......	34.7	243.2	......	......	$MgCl_2$
34.1	......	37.1	......	7.5	......	$MgSO_4$
50.2	80.7	42.9	......	72.4	36.	$MgCO_3$
......	......	......	191.6	......	......	$CaCl_2$
......	......	......	151.8	......	......	$CaSO_4$
161.	158.5	206.9	316.	139.8	38.2	$CaCO_3$
.8	.6	1.	10.4	.6	.4	$FeCO_3$
1.2	.4	1.2	1.6	4.	.9	Al_2O_3
9.	10.5	12.	11.6	15.6	11.6	SiO_2
......	.2	.4	......	......	.4	Bases
416.4	420.3	711.	2212.6	258.9	507.7	Total

(grains per U. S. gallon)

.05	......	......	......	......	......	KNO_2
.33	.33	.10	.17	.12	.24	KNO_3
.93	1.53	1.77	2.78	.07	.12	KCl
......	......	......	......	......	1.59	K_2SO_4
......	......	......	......	......	......	KNO_3
7.12	2.16	19.99	71.98	.82	......	NaCl
......	3.62	......	......	......	5.28	Na_2SO_4
......	2.22	......	......	......	17.18	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
.09	......	.05	.11	.10	......	NH_4Cl
......	......	......	......	......	......	$(NH_4)_2SO_4$
......	.02	......	......	......	.09	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
.81	......	2.02	14.19	......	......	$MgCl_2$
1.99	......	2.16	......	.44	......	$MgSO_4$
2.93	4.71	2.50	......	4.21	2.10	$MgCO_3$
......	......	......	11.18	......	......	$CaCl_2$
......	......	......	8.85	......	......	$CaSO_4$
9.39	9.24	12.07	18.43	8.16	2.23	$CaCO_3$
.05	.03	.06	.61	.03	.02	$FeCO_3$
.07	.02	.07	.09	.23	.05	Al_2O_3
.52	.61	.70	.68	.91	.68	SiO_2
......	.01	.02	......	......	.02	Bases
24.28	24.50	41.51	129.07	15.09	29.60	Total

TABLE I.—*Mineral analyses of underground*

County	Kane	Kane	Kane	Kankakee
Town	Maple Park	St. Charles	St. Charles	Manteno
	(Waterworks)	(Waterworks)	(Park St. well)	(Waterworks)
Owner	Village	City	City	Village
Depth of well.....feet	250	350	850	426
Depth of casing.....feet	250	To bed rock	60	17
Rate of pumping..gals. per min.	40	120	200	100
Date sample was collected	July 31, '15	Aug. 6, '14	Aug. 6, '14	Mar. 30, '14
				Determinations made
Potassium	5.	14.7	13.	6.8
Sodium	26.7	52.8	34.7	18.3
Ammonium	.5	.3	1.	.0
Magnesium	26.9	45.7	30.7	47.2
Calcium	52.4	85.1	64.6	120.7
Iron	.1	.8	.4	.4
Alumina	1.3	2.6	1.5	.6
Nitrites	2.5	.0	.0	.16
Nitrates	.0	22.1	3.9	14.1
Chlorine	2.	27.	4.	28.
Sulphate	23.5	98.1	29.7	184.9
Silica	15.4	15.4	10.7	11.8
Manganese	......	......	......	......
Bases	.2	1.	.06	.4
				Hypothetical combinations
Potassium nitrite	......	......	......	.3
Potassium nitrate	4.1	36.	6.4	17.3
Potassium chloride	3.1	1.5	8.4	......
Potassium sulphate	5.1	......	13.6	......
Sodium nitrate	......	......	......	4.8
Sodium chloride	......	43.4	......	43.1
Sodium sulphate	30.6	110.1	32.8	......
Sodium carbonate	38.7	......	55.4	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	......	......	......
Ammonium sulphate	......	1.1	......	......
Ammonium carbonate	1.3	......	2.7	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	......	......	2.6
Magnesium sulphate	......	28.7	......	229.9
Magnesium carbonate	93.2	138.2	106.3	......
Calcium chloride	......	......	......	......
Calcium sulphate	......	......	......	2.1
Calcium carbonate	130.8	212.4	161.3	300.8
Iron carbonate	.2	1.7	.8	.8
Alumina	1.3	2.6	1.5	.6
Silica	15.4	15.4	10.7	11.8
Manganese carbonate	......	......	......	......
Bases	.2	3.	1.	.4
Total	324.	594.1	400.9	614.5
				Hypothetical combinations
Potassium nitrite	......	......	......	.02
Potassium nitrate	.24	2.10	.37	1.01
Potassium chloride	.18	.09	.49	......
Potassium sulphate	.30	......	.79	......
Sodium nitrate	......	......	......	.28
Sodium chloride	......	2.53	......	2.51
Sodium sulphate	1.78	6.42	1.91	......
Sodium carbonate	2.25	......	3.23	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	......	......	......
Ammonium sulphate	......	.06	......	......
Ammonium carbonate	.08	......	.16	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	......	......	.15
Magnesium sulphate	......	1.67	......	13.41
Magnesium carbonate	5.43	8.06	6.20	......
Calcium chloride	......	......	......	......
Calcium sulphate	......	......	......	.12
Calcium carbonate	7.63	12.39	9.41	17.55
Iron carbonate	.01	.10	.05	.05
Alumina	.08	.15	.09	.03
Silica	.90	.90	.62	.69
Manganese carbonate	......	......	......	......
Bases	.01	.17	.06	.02
Total	18.89	34.64	23.38	35.84

[a] Plus 14 feet of screen.

waters in northeastern Illinois—Continued

Kankakee Reddick	Lake Highland Park	Lake Lake Zurich	La Salle Cedar Point	La Salle Grand Ridge	La Salle La Salle	Chemical formula
(Town Hall)	(1½ miles west in NE. ¼ sec. 21, T. 43 N., R. 12 E.)	(Waterworks)	(Waterworks)	(Waterworks)	(NE. ¼ sec. 35, T. 34 N., R. 1 E)	
Village	Tillman	Village	Cedar Point Light & Water Co.	Village	Mitchell Bros.	
268	180	218	1,750	160	290	
......	165	218	900	[a]146	......	
Not used	Flows, 2	35	75	110	......	
Aug. 11, '13	Aug. 24, '14	June 14, '15	Feb. 7, '13	July 5, '15	July 29, '12	
(parts per million)						
9.	3.6	4.1	29.	3.	3.9	K
1868.3	73.4	111.1	299.5	63.4	17.2	Na
.6	.7	.6	2.	1.8	trace	NH_4
16.8	45.	113.3	.7	13.7	35.	Mg
35.7	55.2	196.6	71.7	24.7	88.8	Ca
2.06	.1	.2	.3	.9	.4	Fe
6.8	2.2	13.	6.9	1.	.6	Al_2O_3
.0	.0	.0	.0	.0	trace	NO_2
2.3	1.8	.3	.8	1.4	1.2	NO_3
2700.	8.	6.	310.	7.	4.	Cl
.0	285.	1087.8	181.6	.0	63.7	SO_4
9.8	20.8	15.	10.5	7.2	14.8	SiO_2
......	......	.0	......	.04	......	Mn
1.8	1.	.1	.0	.0	.8	Bases
(parts per million)						
......	......	......	......	......	......	KNO_2
3.8	2.9	.5	1.3	2.3	2.	KNO_3
14.3	4.8	6.9	54.2	4.	5.9	KCl
......	......	......	......	......	......	K_2SO_4
......	......	......	......	......	......	$NaNO_3$
4444.3	9.4	4.5	469.	8.4	2.	NaCl
......	214.9	337.	268.6	......	41.6	Na_2SO_4
269.7	......	......	63.9	138.3	......	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
......	......	......	......	......	......	NH_4Cl
......	2.6	2.2	......	......	......	$(NH_4)_2SO_4$
1.6	......	......	5.3	4.9	......	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
......	......	......	......	......	......	$MgCl_2$
......	172.9	560.1	......	......	48.2	$MgSO_4$
58.2	34.6	......	2.4	47.4	87.6	$MgCO_3$
......	......	......	......	......	......	$CaCl_2$
......	......	583.9	......	......	......	$CaSO_4$
89.1	137.7	61.4	178.9	61.7	219.7	$CaCO_3$
4.2	.2	.4	.6	11.9	.8	$FeCO_3$
6.8	2.2	13.	6.9	1.	.6	Al_2O_3
9.8	20.8	15.	......	7.2	14.8	SiO_2
......	......	......	10.5	.1	......	$MnCO_3$
1.8	1.	.1	......	.5	.8	Bases
4903.6	604.	1585.	1061.6	277.7	424.	Total
(grains per U. S. gallon)						
......	......	......	......	......	......	KNO_2
.22	.17	.03	.07	.13	.11	KNO_3
.83	.28	.40	3.15	.23	.34	KCl
......	......	......	......	......	......	K_2SO_4
......	......	......	......	......	......	$NaNO_3$
259.24	.55	.26	27.35	.49	.11	NaCl
......	12.53	19.66	15.66	......	2.42	Na_2SO_4
15.73	......	......	3.72	8.07	......	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
......	......	......	......	......	......	NH_4Cl
......	.16	.13	......	......	......	$(NH_4)_2SO_4$
.09	......	......	.30	.29	......	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
......	......	......	......	......	......	$MgCl_2$
......	10.09	32.67	......	......	2.81	$MgSO_4$
3.39	2.02	......	.13	2.76	5.10	$MgCO_3$
......	......	......	......	......	......	$CaCl_2$
......	......	34.06	......	......	......	$CaSO_4$
5.20	8.02	3.58	10.43	3.60	12.81	$CaCO_3$
.24	.01	.02	.03	.11	.05	$FeCO_3$
.40	.13	.76	.40	.06	.03	Al_2O_3
.57	1.21	.87	.61	.42	.86	SiO_2
......	......	......	......	.01	......	$MnCO_3$
.10	.06	......	......	.03	.05	Bases
286.01	35.23	92.44	61.85	16.20	24.69	Total

TABLE I.—*Mineral analyses of underground*

County	La Salle	La Salle	La Salle	La Salle
Town	La Salle (Ill. R. bottom land, 2 wells)	La Salle	Leland (Waterworks)	Marseilles (Waterworks, 2 wells)
Owner	City	Ill. Zinc Co. well No. 4	Village	Consumers Water & Light Co.
Depth of well . . . feet	38 & 39½	1,400	230	800 & 600
Depth of casing . . . feet	38 & 39½	......	100	100
Rate of pumping . . gals. per min.	[b]1500	......	225	[b]100
Date sample was collected	July 30, '12	July 29, '12	Aug. 11, '14	July 3, '15
				Determinations made
Potassium	8.5	36.5	3.6	3.
Sodium	21.1	49.9	10.9	53.6
Ammonium	.37	1.4	.7	.5
Magnesium	39.	21.7	34.3	40.3
Calcium	119.3	52.3	58.6	82.9
Iron	.1	.3	4.8	.1
Alumina	2.8	2.8	3.3	1.1
Nitrites	trace	trace	.0	.0
Nitrates	5.7	.9	1.4	.7
Chlorine	17.	660.	4.	97.
Sulphate	183.8	80.1	1.6	88.
Silica	10.	10.	15.1	.4
Hydrogen sulphide	......	......	......	......
Manganese	......	......	......	......
Bases	12.8	6.8	.6	.6
				Hypothetical combinations
Potassium nitrite	......	......	......	......
Potassium nitrate	9.3	1.5	2.3	1.1
Potassium chloride	9.3	68.4	5.1	5.
Potassium sulphate	......	......	......	......
Sodium nitrate	......	......	......	......
Sodium chloride	20.9	1035.5	2.6	136.
Sodium sulphate	39.8	118.5	2.4	......
Sodium carbonate	......	121.	20.9	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	......	......	1.5
Ammonium sulphate	1.5	......	......	......
Ammonium carbonate	......	......	1.8	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	......	......	16.4
Magnesium sulphate	192.8	......	......	110.3
Magnesium carbonate	......	75.2	118.7	75.8
Calcium chloride	......	......	......	......
Calcium sulphate	2.8	......	......	......
Calcium carbonate	295.6	130.5	145.2	206.9
Iron carbonate	.2	.6	9.8	.2
Alumina	5.6	2.4	3.3	1.1
Silica	10.	10.	15.1	.4
Bases	12.8	6.8	.6	.6
Total	600.6	1570.4	327.8	555.3
				Hypothetical combinations
Potassium nitrite	......	......	......	......
Potassium nitrate	.54	.09	.13	.06
Potassium chloride	.54	3.98	.30	.29
Potassium sulphate	......	......	......	......
Sodium nitrate	......	......	......	......
Sodium chloride	1.21	60.39	.15	7.93
Sodium sulphate	2.32	6.91	.14	......
Sodium carbonate	......	7.06	1.22	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	......	......	.09
Ammonium sulphate	.09	......	......	......
Ammonium carbonate	......	......	.11	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	......	......	.96
Magnesium sulphate	11.24	......	......	6.43
Magnesium carbonate	......	4.38	6.92	4.42
Calcium chloride	......	......	......	......
Calcium sulphate	.16	......	......	......
Calcium carbonate	17.23	7.61	8.47	12.07
Iron carbonate	.01	.03	.57	.01
Alumina	.33	.14	.19	.06
Silica	.58	.58	.88	.02
Bases	.75	.39	.04	.03
Total	35.00	91.56	19.12	32.37

[b] Combined.

waters in northeastern Illinois—Continued

La Salle Mendota (Waterworks)	La Salle Ottawa (Sanicula Mineral Spring)	La Salle Peru	La Salle Peru	La Salle Ransom	La Salle Streator	
City	E.P. Mitschelm	......	Western Clock Co. well No. 3	Village	Western Glass Co.	Chemical formula
490	Spring	1,505	1,263	274	640	
260	8	......	......	......	......	
200	Flows, 5	......	Flows	......	60	
Aug. 3, '15	Aug. 2, '15	Dec. 22, '13	July 29, '12	Mar. 24, '13	Oct. 31, '11	
(parts per million)						
1.8	39.5	18.4	30.4	15.6	26.3	K
30.1	732.8	545.7	192.6	123.4	192.8	Na
3.3	1.8	1.4	1.3	.4	.9	NH_4
25.1	105.	23.9	10.5	16.3	11.9	Mg
70.7	319.	50.6	51.5	31.4	48.9	Ca
3.2	.1	4.	.6	.3	.2	Fe
5.	2.	.3	1.6	5.	44.	Al_2O_3
.0	.0	.0	.0	.0	.0	NO_2
1.8	1.8	.4	5.	2.1	5.8	NO_3
1.	1700.	750.	150.	26.	210.	Cl
2.8	196.6	74.9	110.2	9.	61.6	SO_4
24.5	12.	12.	12.8	19.2	9.6	SiO_2
......	......	......	......	......	14.5	H_2S
......	.0	......	......	......	......	Mn
.6	3.	1.6	.6	......	......	Bases
(parts per million)						
......	......	......	......	......	......	KNO_2
2.9	2.9	.7	.8	3.4	9.5	KNO_3
1.3	73.2	34.5	57.4	27.1	43.1	KCl
......	......	......	......	......	......	K_2SO_4
......	......	......	......	......	......	$NaNO_3$
.7	1859.8	1210.5	202.5	21.7	312.7	NaCl
4.1	......	109.5	163.1	13.3	91.2	Na_2SO_4
65.6	......	78.5	137.8	254.7	92.1	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
......	5.3	......	......	......	......	NH_4Cl
......	......	......	......	......	......	$(NH_4)_2SO_4$
8.8	......	3.7	3.5	1.	4.7	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
......	410.6	......	......	......	......	$MgCl_2$
......	......	......	......	......	......	$MgSO_4$
86.9	......	83.	36.4	56.5	41.2	$MgCO_3$
......	358.9	......	......	......	......	$CaCl_2$
......	283.	......	......	......	......	$CaSO_4$
176.5	265.8	126.3	128.5	78.3	122.1	$CaCO_3$
6.6	.2	8.3	1.2	.6	.4	$FeCO_3$
5.	2.	.3	1.6	5.	44.	Al_2O_3
24.5	12.	12.	12.8	19.2	9.6	SiO_2
.6	3.	1.6	.6	......	......	Bases
383.5	3276.9	1668.9	746.2	480.8	770.6	Total
(grains per U. S. gallon)						
......	......	......	......	......	......	KNO_2
.17	.17	.04	.05	.9	.55	KNO_3
.08	4.27	2.01	3.34	1.57	2.51	KCl
......	......	......	......	......	......	K_2SO_4
......	......	......	......	......	......	$NaNO_3$
.04	108.48	70.61	11.81	1.26	18.24	NaCl
.24	......	6 38	9.51	.77	5.32	Na_2SO_4
3.83	......	4.58	8.04	14.85	5.38	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
......	.31	......	......	......	......	NH_4Cl
......	......	......	......	......	......	$(NH_4)_2SO_4$
.51	......	.22	.20	.05	.27	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
......	23.95	......	......	......	......	$MgCl_2$
......	......	......	......	......	......	$MgSO_4$
5.07	......	4.84	2.12	3.28	2.40	$MgCO_3$
......	20.93	......	......	......	......	$CaCl_2$
......	16.51	......	......	......	......	$CaSO_4$
10.30	15.50	7.37	7.49	4.55	7.13	$CaCO_3$
.38	.01	.48	.07	.03	.02	$FeCO_3$
.29	.12	.02	.09	.29	2.57	Al_2O_3
1.43	.70	.70	.75	1.12	.56	SiO_2
.03	.17	.09	.03	......	......	Bases
22.37	191.12	97.34	43.50	27.96	44.95	Total

TABLE I.—*Mineral analyses of underground*

County	La Salle	La Salle	La Salle	La Salle
Town	Streator	Streator	Streator	Streator
		(Brick Plant)	(near city Park)	(water from Vermilion River)
Owner	Vulcan Detinning Co.	Streator Paving Brick Co.	City	City
Depth of well feet	563	660	2,496	(Average of 12 monthly analyses)
Depth of casing feet	200	......	......	
Rate of pumping..gals. per min.	60	......	Flows	
Date sample was collected	Oct. 31, '11	Oct. 31, '11	Oct. 31, '11	
Determinations made (parts				
Potassium	49.	49.7	346.8	{ 18.
Sodium	312.2	300.7	3732.	
Ammonium	1.1	1.5	5.	......
Magnesium	8.8	23.9	143.3	29.
Calcium	61.8	56.	693.3	55.
Iron	.3	trace	6.3	.2
Alumina	trace	trace	10.	.0
Nitrites	.0	.0	.0	.0
Nitrates	.9	.5	.2	12.
Chlorine	410.	410.	7100.	6.9
Sulphate	21.7	62.1	403.2	68.
Silica	12.8	10.	12.	14.
Hydrogen sulphide	15 (est.)	15.	......	......
Manganese	......	......	......	......
Bases	.0	.0	.0	.0
Hypothetical combinations				
Potassium nitrite	......	......	......	......
Potassium nitrate	1.5	.8	.3	......
Potassium chloride	92.2	94.1	470.1	......
Potassium sulphate	......	......	......	......
Sodium nitrate	......	......	......	16.4
Sodium chloride	604.3	602.8	9471.7	11.5
Sodium sulphate	32.1	91.9	......	23.1
Sodium carbonate	146.4	76.9	......	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	......	14.8	......
Ammonium sulphate	......	......	......	......
Ammonium carbonate	2.9	......	......	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	......	560.4	......
Magnesium sulphate	......	......	......	67.7
Magnesium carbonate	23.6	82.8	......	53.
Calcium chloride	......	......	1268.1	......
Calcium sulphate	......	......	571.5	......
Calcium carbonate	154.3	139.8	167.	137.3
Iron carbonate	.6	trace	13.	.4
Alumina	trace	trace	10.	......
Silica	12.8	10.	12.	14.
Bases	......	......	......	......
Total	1070.7	1099.1	12558.9	323.4
Hypothetical combinations				
Potassium nitrite	......	......	......	......
Potassium nitrate	.09	.05	.02	......
Potassium chloride	5.38	5.49	27.43	......
Potassium sulphate	......	......	......	......
Sodium nitrate	......	......	......	.95
Sodium chloride	35.25	35.16	552.48	.67
Sodium sulphate	1.88	5.36	......	1.35
Sodium carbonate	8.54	4.48	......	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	......	.86	......
Ammonium sulphate	......	......	......	......
Ammonium carbonate	.17	......	......	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	......	32.68	......
Magnesium sulphate	......	......	......	3.94
Magnesium carbonate	1.37	4.83	......	3.09
Calcium chloride	......	......	73.97	......
Calcium sulphate	......	......	33.34	......
Calcium carbonate	9.00	8.16	9.74	8.00
Iron carbonate	.03	trace	.76	.02
Alumina	trace	trace	.58	......
Silica	.75	.58	.70	.81
Bases	......	......	......	......
Total	62.46	64.11	732.56	18.83

waters in northeastern Illinois—Continued

La Salle Utica	La Salle Utica	La Salle Utica	La Salle Wedron	McHenry Algonquin	McHenry Crystal Lake	
(northwest part of village)	(near village hall)	(on Clark St. S. of canal)	(1 mile S. of village)	(½ mi. NE. of town)	(Waterworks)	
Village	Village	Village	Sulphur Lick Springs Hotel	Village	Village	Chemical formula
225—350	225—350	225—350	Spring	Spring	(Dug) 32	
140	140	140	......	......	......	
Flows, 125	Flows, 125	Flows, 125	Flows, 1,050	Flows, 500	215	
Aug. 1, '12	Dec. 16, '13	Dec. 16, '13	July 30, '15	June 1, '15	Oct. 31, '13	

per million)

4.5	6.9	4.9	3.8	2.5	2.8	K
12.3	28.4	14.9	19.5	5.2	18.8	Na
.7	.9	.7	.7	.0	.0	NH_4
34.1	33.	29.	37.1	31.7	35.6	Mg
81.	86.2	85.	72.3	65.	90.2	Ca
1.3	.5	.7	.05	.07	.06	Fe
1.1	.5	.2	1.2	1.4	.4	Al_2O_3
trace	.0	.0	.0	.0	.3	NO_2
1.1	.7	2.4	3.5	14.1	5.7	NO_3
3.4	55.	21.	12.	3.	9.	Cl
5.4	6.8	4.4	23.8	44.8	52.	SO_4
11.	10.5	12.	9.2	10.9	13.6	SiO_2
......	......	......	......	......	......	H_2S
......	......	......	.0	.0	......	Mn
.2	.0	1.2	.5	3.3	.0	Bases

(parts per million)

......	......	......	......	......	.5	KNO_2
1.8	1.1	3.9	5.7	6.5	6.7	KNO_3
7.2	12.4	6.5	3.	......	......	KCl
......	......	......	......	......	......	K_2SO_4
......	......	......	......	13.8	2.5	$NaNO_3$
31.2	72.	28.8	17.5	3.8	14.8	NaCl
......	......	6.5	35.2	......	37.9	Na_2SO_4
......	......	4.3	2.8	......	......	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
2.1	2.6	......	......	......	......	NH_4Cl
......	......	......	......	......	......	$(NH_4)_2SO_4$
......	......	1.9	1.9	......	......	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
13.8	5.1	......	......	.9	......	$MgCl_2$
6.8	8.5	......	......	56.2	33.	$MgSO_4$
101.1	103.9	100.4	128.5	69.6	100.4	$MgCO_3$
......	......	......	......	......	......	$CaCl_2$
......	......	......	......	......	......	$CaSO_4$
202.2	215.1	212.2	180.4	162.3	225.	$CaCO_3$
3.2	1.	1.4	.1	.1	.1	$FeCO_3$
1.1	.5	.2	1.2	1.4	.4	Al_2O_3
11.	10.3	12.	9.2	10.9	13.6	SiO_2
.2	.0	1.2	.5	3.3	.2	Bases
381.7	432.5	379.3	386.	328.8	435.1	Total

(grains per U. S. gallon)

......	......	......	......	......	.03	KNO_2
.10	.06	.22	.33	.38	.39	KNO_3
.42	.72	.38	.17	......	......	KCl
......	......	......	......	......	......	K_2SO_4
......	......	......	......	.80	.15	$NaNO_3$
1.82	4.20	1.68	1.02	.22	.86	NaCl
......	......	.38	2.05	......	2.21	Na_2SO_4
......	......	.25	.16	......	......	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
.12	.15	......	......	......	......	NH_4Cl
......	......	......	......	......	......	$(NH_4)_2SO_4$
......	......	.11	.11	......	......	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
.80	.30	......	......	.05	......	$MgCl_2$
.40	.50	......	......	3.27	1.92	$MgSO_4$
5.89	6.06	5.85	7.49	4.06	5.85	$MgCO_3$
......	......	......	......	......	......	$CaCl_2$
......	......	......	......	......	......	$CaSO_4$
11.79	12.55	12.37	10.52	9.46	13.12	$CaCO_3$
.19	.06	.08	.01	.01	.01	$FeCO_3$
.06	.03	.01	.07	.08	.02	Al_2O_3
.64	.60	.70	.54	.63	.79	SiO_2
.01	.00	.07	.03	.19	.01	Bases
22.24	25.23	22.10	22.50	19.15	25.36	Total

TABLE I.—*Mineral analyses of underground*

County	McHenry	McHenry	McHenry	Will
Town	Marengo (Waterworks)	North Crystal Lake (Waterworks)	Woodstock (Pumping station No. 2, 2 wells)	Braidwood (Waterworks)
Owner	Village	Village	City	Village
Depth of well . . . feet	(Dug) 14	285	(both) 85	(Dug) 20
Depth of casing . . . feet	......	260	[c]67	......
Rate of pumping . . . gals. per min.	200	200	[d]350	100
Date sample was collected	Oct. 28, '13	Oct. 31, '13	Mar. 23, '14	June 22, '14

Determinations made

Potassium	2.7	3.5	2.7	8.2
Sodium	6.3	24.4	12.5	14.6
Ammonium	.1	.6	.6	.2
Magnesium	36.5	32.8	41.9	26.7
Calcium	84.3	52.3	76.4	93.2
Iron	.1	.3	2.6	.3
Alumina	1.2	2.5	.5	1.6
Nitrites	.0	.0	.0	.0
Nitrates	23.8	.3	2.2	22 9
Chlorine	15.	15.	2.	6.
Sulphate	53.3	8.9	6.6	179.2
Silica	13.5	17.8	26.2	10.
Manganese	......	.0	......	......
Bases	1.	.0	1.3	1.

Hypothetical combinations

Potassium nitrite	......	......	......	......
Potassium nitrate	7.	.5	3.6	21.2
Potassium chloride	......	6.3	2.5	......
Potassium sulphate	......	......	......	......
Sodium nitrate	23.2	......	......	13.6
Sodium chloride	......	19.8	1.2	9.9
Sodium sulphate	......	13.2	9.8	23.1
Sodium carbonate	......	28.3	20.3	......
Ammonium nitrate	.3	......	......	......
Ammonium chloride	......	......	......	......
Ammonium sulphate	......	......	......	.7
Ammonium carbonate	......	1.6	1.6	......
Magnesium nitrate	2.9	......	......	......
Magnesium chloride	20.1	......	......	......
Magnesium sulphate	66.8	......	......	132.
Magnesium carbonate	60.2	113.4	145.1	......
Calcium chloride	......	......	......	......
Calcium sulphate	......	......	......	81.9
Calcium carbonate	210.3	130.5	190.7	172.5
Iron carbonate	.2	.7	5.4	.6
Alumina	1.2	2.5	.5	1.6
Silica	13.5	17.8	26.2	10.
Bases	1.	.0	1.3	1.
Total	406.7	334.6	408.2	468.1

Hypothetical combinations

Potassium nitrite	......	......	......	......
Potassium nitrate	.40	.03	1.21	1.24
Potassium chloride	......	.37	.15	.04
Potassium sulphate	......	......	......	......
Sodium nitrate	1.35	......	......	.79
Sodium chloride	......	1.15	.07	.58
Sodium sulphate	......	.77	.57	1.35
Sodium carbonate	......	1.65	.18	......
Ammonium nitrate	.02	......	......	......
Ammonium chloride	......	......	......	......
Ammonium sulphate	......	......	......	......
Ammonium carbonate	......	.09	.09	......
Magnesium nitrate	.17	......	......	......
Magnesium chloride	1.17	......	......	......
Magnesium sulphate	3.89	......	......	7.70
Magnesium carbonate	3.51	6.61	8.46	......
Calcium chloride	......	......	......	......
Calcium sulphate	......	......	......	4.78
Calcium carbonate	12.26	7.61	11.12	10.06
Iron carbonate	.01	.04	.31	.03
Alumina	.07	.15	.03	.09
Silica	.79	.04	1.53	.58
Bases	.06	.9	.08	.06
Total	23.70	19.51	23.80	27.30

[c] Plus 18 feet of screen. [d] Combined. [c] Plus 10 feet of screen.

waters in northeastern Illinois—Continued

Will Crete	Will Joliet	Will Joliet	Will Joliet	Will Lockport	Will Mokena	
(Waterworks)	(Desplaines St. Station)	(City High School)	(Canal St. well)	(Water-works)	(Water-works)	Chem-ical formula
Village	City	City	......	City	City	
192	1,575	881	1,565	1,650	139	
150	300	500	......	51	[a]129	
90	450	25	......	160	60	
June 29, '15	Sept. 27, '15	Sept. 27, '15	May 15, '13	July 2, '15	July 1, '15	

(parts per million)

4.2	23.9	20.6	11.2	21.	3.4	K
10.1	104.	106.8	83.	190.	11.7	Na
.4	.9	.9	2.	.5	.5	NH_4
35.1	18.5	20.7	9.9	48.4	43.4	Mg
102.6	51.5	50.	68.8	144.7	144.4	Ca
.9	.4	.2	......	.1	.6	Fe
1.3	9.	2.8	......	2.3	3.3	Al_2O_3
[illegible]	.0	.0	......	.04	.0	NO_2
.7	.0	.4	2.2	10.6	.7	NO_3
2.	47.	59.	36.	410.	1.	Cl
21.6	113.6	116.9	88.9	188.4	148.	SO_4
11.6	21.4	10.	......	14.	16.	SiO_2
......	.0	.0	......	......	......	Mn
.8	......	......	......	2.	1.2	Bases

(parts per million)

......	......	......	......	.1	......	KNO_2
1.1	......	.6	3.5	17.3	1.	KNO_3
4.2	45.5	38.9	18.8	27.2	1 7	KCl
3.6	......	......	......	......	5.3	K_2SO_4
......	......	......	......	......	......	$NaNO_3$
......	42.2	65.2	44.6	482.2	......	NaCl
29.	168.	173.	131.4	......	36.1	Na_2SO_4
1.6	75.5	58.	53.2	......	......	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
......	......	......	......	1.5	......	NH_4Cl
......	......	......	......	......	1.8	$(NH_4)_2SO_4$
1.1	2.4	2.4	5.3	......	......	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
......	......	......	......	139.6	......	$MgCl_2$
......	......	......	......	62.8	1[illegible]	$MgSO_4$
121.6	64.1	71.7	34.3	......	41.9	$MgCO_3$
......	......	......	......	......	......	$CaCl_2$
......	......	......	......	196.	......	$CaSO_4$
256.1	128.5	124.8	171.7	217.2	360.5	$CaCO_3$
1.9	.8	.4	......	.2	1.2	$FeCO_3$
1 3	9.	2.8	25.4	2.3	3.3	Al_2O_3
11.6	21.4	10.	9.	14.	16.	SiO_2
.8	......	......	......	2.	1.2	Bases
433.9	557.4	547.8	497.2	1162.4	619.7	Total

(grains per U. S. gallon)

......	......	......	......	.01	......	KNO_2
.06	......	.03	.20	1.01	.06	KNO_3
.24	2.65	2.27	1.09	1.59	.10	KCl
.21	......	......	......	......	.31	K_2SO_4
......	......	......	......	......	......	$NaNO_3$
......	2.46	3.80	2.59	28.13	......	NaCl
1.69	9.80	10.09	7.66	......	2.11	Na_2SO_4
.09	4.40	3.38	3.10	......	......	Na_2CO_3
......	......	......	......	......	......	NH_4NO_3
......	......	......	......	.09	......	NH_4Cl
......	......	......	......	......	.10	$(NH_4)_2SO_4$
.06	.14	.14	.30	......	......	$(NH_4)_2CO_3$
......	......	......	......	......	......	$Mg(NO_3)_2$
......	......	......	......	8.14	......	$MgCl_2$
......	......	......	......	3.66	8.73	$MgSO_4$
7.09	3.73	4.18	1.99	......	2.44	$MgCO_3$
......	......	......	......	......	......	$CaCl_2$
......	......	......	......	11.43	......	$CaSO_4$
14.94	7.49	7.28	10 01	12.67	21.03	$CaCO_3$
.11	.05	.02	......	.01	.07	$FeCO_3$
.08	.52	.16	1.47	.13	.19	Al_2O_3
.68	1.25	.58	.52	.82	.93	SiO_2
.05	......	......	......	.12	.07	Bases
25.30	32.49	31.93	28.93	67.81	36.14	Total

TABLE I.—*Mineral analyses of underground*

County	Will	Will	Will	Will
Town	Monee (Waterworks, well No. 1)	Monee (Waterworks) well No. 2)	Peotone (Waterworks)	Plainfield ......
Owner	Village	Village	Village	Village
Depth of well .... feet	166	169	135	104
Depth of casing .... feet	90	90	135	......
Rate of pumping.... gals. per min.	35	165	150	......
Date sample was collected	June 29, '15	June 29 '15	April 9, '06	......
				Determinations made
Potassium	5.7	5.4	5.	......
Sodium	15.9	30.5	34.5	123.4
Ammonium	1.3	.7	.7	......
Magnesium	49.4	79.8	33.8	64 2
Calcium	204.4	110.1	85.1	79.1
Iron	8.	1.2	1.6	([f])
Alumina	1.	2.5	6.8	([f])
Nitrites	.03	.03	......	......
Nitrates	.4	1.1	.9	61.9
Chlorine	3.	3.	4.	204.
Sulphate	370.1	215.8	16.21	136.
Silica	14.	20.6	16.1	19.4
Manganese	......	......	......	......
Bases	1.2	.07	1.9	4.8
				Hypothetical combinations
Potassium nitrite	.1	.1	......	......
Potassium nitrate	.7	1.8	1.5	......
Potassium chloride	6.3	6.3	8.3	......
Potassium sulphate	4.7	3.1	......	......
Sodium nitrate	......	......	......	84.9
Sodium chloride	......	......	......	254.8
Sodium sulphate	49.	94.1	106.4	......
Sodium carbonate	......	......	......	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	......	......	......
Ammonium sulphate	4.8	2.6	2.6	......
Ammonium carbonate	......	......	......	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	......	......	66.6
Magnesium sulphate	244.2	186.3	110.7	171.
Magnesium carbonate	......	145.8	39.5	42.2
Calcium chloride	......	......	......	......
Calcium sulphate	192 9	......	......	......
Calcium carbonate	367.4	274 8	212.4	198.
Iron carbonate	16 6	2.5	3 3	......
Iron oxide	......	......	......	} 13.
Alumina	1.	2.5	6.8	
Silica	14.	20.6	16.1	19.4
Bases	1.2	1.2	1.9	4.8
Total	902.9	741.7	509.5	854.7
				Hypothetical combinations
Potassium nitrite	.01	.01	......	......
Potassium nitrate	.04	.10	.09	......
Potassium chloride	.37	.37	.48	......
Potassium sulphate	.27	.18	......	......
Sodium nitrate	......	......	......	4.95
Sodium chloride	......	......	......	14.87
Sodium sulphate	2.86	5.49	6.20	......
Sodium carbonate	......	......	......	......
Ammonium nitrate	......	......	......	......
Ammonium chloride	......	......	......	......
Ammonium sulphate	.28	.15	.15	......
Ammonium carbonate	......	......	......	......
Magnesium nitrate	......	......	......	......
Magnesium chloride	......	......	......	3.88
Magnesium sulphate	14.24	10.87	6.46	9.97
Magnesium carbonate	......	8.45	2.30	2.46
Calcium chloride	......	......	......	......
Calcium sulphate	11.25	......	......	......
Calcium carbonate	21.43	16.03	12.39	11.55
Iron carbonate	.97	.15	.19	......
Iron oxide	......	......	......	} .76
Alumina	.06	.15	.40	
Silica	.82	1.20	.94	1.13
Bases	.07	.07	.11	.28
Total	52.67	43.22	29.71	49.85

[f] Ferric oxide and alumina.

waters in northeastern Illinois—Concluded

Will Rockdale (Waterworks)	Will Steger (Waterworks)	Winnebago Pecatonica (Waterworks)	Winnebago Rockford (1602 S. Main St.)	......	......	Chemical formula
Village	Village	Village	Graham Bros.	......	......	
662	318	(Dug) 20	175	......	......	
260	147	......	......	......	......	
160	300	130	Flows	......	......	
July 2, '15	April 1, '14	Oct. 18, '13	......	......	......	

(parts per million)

17.8	7.2	2.	2.4	......	......	K
91.6	18.4	3.2	4.4	......	......	Na
1.8	.06	.04	.1	......	......	NH_4
21.8	39.5	39.3	36.9	......	......	Mg
58.	86.6	67.9	89.9	......	......	Ca
.6	1.	.1	.1	......	......	Fe
.9	1.4	.3	.4	......	......	Al_2O_3
.05	......	.0	.1	......	......	NO_2
.7	2.3	.5	26.2	......	......	NO_3
47.	2.	4.	11.	......	......	Cl
117.6	47.2	38.5	22.8	......	......	SO_4
7.8	11.6	24.	16.5	......	......	SiO_2
......	......	.0	......	......	......	Mn
.6	1.	.8	1.5	......	......	Bases

(parts per million)

.1	......	......	.2	......	......	KNO_2
1.1	3.8	.8	5.9	......	......	KNO_3
33.2	4.2	3.2	......	......	......	KCl
......	7.6	......	......	......	......	K_2SO_4
......	......	......	10.1	......	......	$NaNO_3$
51.5	......	4.1	......	......	......	NaCl
174.	56.7	4.9	......	......	......	Na_2SO_4
34.3	......	......	......	......	......	Na_2CO_3
......	......	......	.4	......	......	NH_4NO_3
......	......	......	......	......	......	NH_4Cl
......	......	.1	......	......	......	$(NH_4)_2SO_4$
......	......	......	......	......	......	$(NH_4)_2CO_3$
......	......	......	19.8	......	......	$Mg(NO_3)_2$
......	......	......	14.8	......	......	$MgCl_2$
......	5.9	44.2	28.6	......	......	$MgSO_4$
75.5	132.6	105.	83.4	......	......	$MgCO_3$
......	......	......	......	......	......	$CaCl_2$
......	......	......	......	......	......	$CaSO_4$
144.8	216.2	169.5	224.4	......	......	$CaCO_3$
1.2	2.	.2	.2	......	......	$FeCO_3$
......	......	......	......	......	......	Fe_2O_3
.9	1.4	.3	.4	......	......	Al_2O_3
7.8	11.6	24.	16.5	......	......	SiO_2
.6	1.	.8	1.4	......	......	Bases
525.	443.	357.1	406.1	......	......	Total

(grains per U. S. gallon)

.01	......	......	.01	......	......	KNO_2
.06	.22	.05	.34	......	......	KNO_3
1.94	.24	.19	......	......	......	KCl
......	.44	......	......	......	......	K_2SO_4
......	......	......	.59	......	......	$NaNO_3$
3.00	......	.24	......	......	......	NaCl
10.15	3.31	.29	......	......	......	Na_2SO_4
2.00	......	......	......	......	......	Na_2CO_3
......	......	......	.02	......	......	NH_4NO_3
......	......	......	......	......	......	NH_4Cl
......	......	.01	......	......	......	$(NH_4)_2SO_4$
......	......	......	......	......	......	$(NH_4)_2CO_3$
......	......	......	1.15	......	......	$Mg(NO_3)_2$
......	......	......	.86	......	......	$MgCl_2$
......	.34	2.59	1.67	......	......	$MgSO_4$
4.40	7.73	6.12	4.86	......	......	$MgCO_3$
......	......	......	......	......	......	$CaCl_2$
......	......	......	......	......	......	$CaSO_4$
8.45	12.61	9.88	13.08	......	......	$CaCO_3$
.07	.12	.01	.01	......	......	$FeCO_3$
......	......	......	......	......	......	Fe_2O_3
.05	.08	.02	.02	......	......	Al_2O_3
.45	.68	.40	.96	......	......	SiO_2
.03	.06	.05	.08	......	......	Bases
30.61	25.83	20.85	23.65	......	......	Total

TABLE II.—*Boiler analyses of underground*

County	Boone	Cook	Cook
Town	Belvidere (Round House)	Argo	Argo ......
Owner	C. & N. W. R. R.	Corn Products Refining Co. Well No. 1	Corn Products Refining Co. Well No. 2
Depth of well ... feet	1231	1638	1507
Depth of casing ... feet	To bed rock	45	79
Rate of pumping ... gals. per min.	150	200	375
Date sample was collected	Sept. 29, 1914	July 14, 1914	July 14, 1914

Determinations made

Magnesium (as $CaCO_3$)	136.	236.	240.
Iron	.2	.2	.2
Nitrate nitrogen	.4	.08	.0
Nitrate	1.7	.35	.0
Chlorine	4.	57.	120.
Sulphate	28.4	276.5	296.7
Residue	284.	800.	896.
Alkalinity (as $CaCO_3$)	254.	286.	270.
Non-carbonate hardness (as $CaCO_3$)	14.	192.	196.
Hydrogen sulphide	......	.28	.16

Hypothetical combinations

Sodium nitrate	2.3	.5	......
Sodium chloride	6.6	94.1	198.
Sodium sulphate	22.2	137.5	161.5
Sodium carbonate	......	......	......
Magnesium sulphate	16.8	230.4	235.2
Magnesium carbonate	102.5	37.	37.
Calcium sulphate	......	......	......
Calcium carbonate	132.	242.	226.
Iron carbonate	.4	.4	.4
Undetermined	1.2	58.1	37.9
Total	284.	800.	896.

Hypothetical combinations

Sodium nitrate	.13	.03	......
Sodium chloride	.38	5.49	11.55
Sodium sulphate	1.29	8.02	9.42
Sodium carbonate	......	......	......
Magnesium sulphate	.98	13.44	13.72
Magnesium carbonate	5.96	2.16	2.16
Calcium sulphate	......	......	......
Calcium carbonate	7.70	14.12	13.18
Iron carbonate	.02	.02	.02
Undetermined	.07	3.39	2.21
Total	16.53	46.67	52.26

waters in northeastern Illinois

Cook	Cook	Cook	Cook	Cook
Argo	Argo	Argo	Argo	Barrington
......	......	......	......	(City Water-works)
Corn Products Refining Co. Well No. 3	Corn Products Refining Co. Well No. 5	Corn Products Refining Co. Well No. 6	Corn Products Refining Co. Well No. 7	City
1590	1597	1635	1870	315
61	70	67	44	200
250	250	360	200	400
July 14, 1914	July 14, 1914	July 14, 1914	July 14, 1914	Aug. 18, 1914

(parts per million)

256.	256.	332.	168.	220.
.7	.2	.1	.1	.1
.08	.0	.0	.0	.4
.35	.0	.0	.0	1.8
83.	82.	120.	110.	1.
316.4	334.9	503.	195.9	77.8
829.	892.	1188.	735.	381.
238.	243.	248.	284.	260.
—232.	228.	348.	36.	60.
.17	......	.10	.21	......

(parts per million)

.5	......	......	......	2.5
137.	135.3	198.	181.5	1.7
163.2	172.7	251.7	238.7	30.
......	......	......	......	......
258.4	273.6	398.4	43.2	72.
20.2	23.5	......	110.9	117.6
......	......	21.8	......	......
214.	215.	248.	152.	120.
1.5	.4	.2	.2	.2
34.2	71.5	69.9	8.5	37.
829.	892.	1188.	735.	381.

(parts per U. S. gallon)

.03	......	......	......	.15
7.99	7.89	11.55	10.58	.1
9.52	10.07	14.68	13.92	1.75
......	......	......	......	......
15.07	15.96	23.24	2.53	4.2
1.18	1.37	......	6.47	6.86
......	......	1.27	......	......
12.48	12.54	14.47	8.87	7.
.09	.02	.01	.01	.01
1.99	4.17	4.07	.50	2.16
48.35	52.02	69.29	42.88	22.23

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Berwyn (City waterworks)	Blue Island (City waterworks)	Blue Island (City waterworks)
Owner	City	City Well No. 1	City Well No. 3
Depth of well....feet	1650±	1100±	1649
Depth of casing....feet	36	69±	69
Rate of pumping....gals. per min.	225	200	300
Date sample was collected	Sept. 11, 1914	June 22, 1914	June 11, 1914

Determinations made

Magnesium (as $CaCO_3$)	144.	148.	124.
Iron	.4	.4	.0
Nitrate nitrogen	.72	.08	.28
Nitrate	3.18	.4	1.20
Chlorine	100.	190.	160.
Sulphate	210.1	463.3	471.1
Residue	727.	1248.	1164.
Alkalinity (as $CaCO_3$)	252.	224.	222.
Non-carbonate hardness (as $CaCO_3$)	130.	328.	176.
Hydrogen sulphide	......	......	......

Hypothetical combinations

Sodium nitrate	4.4	.5	1.6
Sodium chloride	165.	313.5	264.
Sodium sulphate	126.7	220.8	447.5
Sodium carbonate	......	......	......
Magnesium sulphate	156.	177.6	148.8
Magnesium carbonate	11.8	......	......
Calcium sulphate	......	244.8	70.7
Calcium carbonate	238.	224.	222.
Iron carbonate	.8	.8	......
Undetermined	24.3	66.	9.4
Total	727.	1248.	1164.

Hypothetical combinations

Sodium nitrate	.26	.03	.09
Sodium chloride	9.62	18.28	15.40
Sodium sulphate	7.39	12.88	26.09
Sodium carbonate	......	......	......
Magnesium sulphate	9.10	10.35	8.68
Magnesium carbonate	.69	......	......
Calcium sulphate	......	14.27	4.12
Calcium carbonate	13.88	13.07	12.95
Iron carbonate	.05	.05	......
Undetermined	1.42	3.85	.55
Total	42.41	72.78	67.88

waters in northeastern Illinois—Continued

Cook Blue Island (Division and 127th St.)	Cook Blue Island (Gas Plant)	Cook Chicago	Cook Chicago (651 E. 39th St.)	Cook Chicago (915 Fulton St.)
Chicago Copper & Chemical Co.	Public Service Company of Northern Illinois	Armour Ammonia Works	Bissel Laundry	Broman Building
1450	2100±	1600	200±	200
48	26	......	To bed rock	To bed rock
50	50	......	25	15
June 20, 1914	June 11, 1914	Oct. 7, 1915	Aug. 29, 1914	Aug. 15, 1914

(parts per million)

152.	68.	......	12.	84.
.4	.1	.5	.6	.2
.80	.32	......	.00	.0
3.50	1.40	4.07	.00	.0
142.	570.	12.	15.	10.
355.9	170.3	......	28.	14.8
1060.	1506.	450.	208.	209.
256.	300.	277.	116.	146.
104.	—12.	......	—14.	—26.
......	......	......	5.87	.577

(parts per million)

4.8	1.9	6.	......	......
233.3	940.6	20.	24.8	16.5
379.4	252.	124.	41.4	21.9
......	12.7	......	14.8	27.6
124.8	......	29.	......	......
40.3	57.1	30.	10.1	70.6
......	......	......	......	......
208.	220.	241.	90.	36.
.8	.2	1.	1.2	.4
68.6	21.5	......	25.7	36.
1060.	1506.	451.	208.	209.

(parts per U. S. gallon)

.28	.11	.35	......	......
13.66	54.86	1.17	1.45	.96
22.12	14.70	7.35	2.41	1.28
......	.74	......	.86	1.61
7.28	......	1.69	......	......
2.35	3.32	1.75	.59	4.11
......	......	......	......	......
12.13	12.83	14.06	5.25	2.10
.05	.01	.06	.07	.02
3.99	1.25	......	1.50	2.10
61.86	87.82	26.31	12.13	12.18

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (313 N. Ann St.)	Chicago (102nd St. & Slip No. 2)	Chicago (105th St. & Ft. Wayne R. R.)
Owner	W. H. Bunge Vinegar Works	Calumet Elevator Co.	Columbia Malting Co.
Depth of well feet	312	363	340
Depth of casing feet	92	75	93
Rate of pumping gals. per min.	12	20	3
Date sample was collected	Aug. 28, 1914	Aug. 7, 1914	Aug. 7, 1914

Determinations made

Magnesium (as $CaCO_3$)	8.	56.	48.
Iron	.0	.8	.2
Nitrate nitrogen	.00	.00	.00
Nitrate	.00	.00	.00
Chlorine	4.	26.	18.
Sulphate	23.4	0.	6.2
Residue	183.	255.	287.
Alkalinity (as $CaCO_3$)	126.	174.	209.
Non-carbonate hardness (as $CaCO_3$)	12.	—142.	—176.
Hydrogen sulphide	.56	.507	......

Hypothetical combinations

Sodium nitrate	......	......	......
Sodium chloride	6.6	42.9	29.7
Sodium sulphate	17.6	......	9.2
Sodium carbonate	......	150.5	186.3
Magnesium sulphate	9.6	......	......
Magnesium carbonate	......	47.	40.2
Calcium sulphate	5.4	......	......
Calcium carbonate	126.	......	......
Iron carbonate	......	1.7	.4
Undetermined	17.8	12.9	21.2
Total	183.	255.	287.

Hypothetical combinations

Sodium nitrate	......	......	......
Sodium chloride	.38	2.49	1.73
Sodium sulphate	1.03	......	.54
Sodium carbonate	......	8.77	10.86
Magnesium sulphate	.56	......	......
Magnesium carbonate	......	2.74	2.36
Calcium sulphate	.31	......	......
Calcium carbonate	7.40	......	......
Iron carbonate	......	.10	.02
Undetermined	1.04	.75	1.24
Total	10.72	14.85	16.75

waters in northeastern Illinois—Continued

Cook Chicago (435 W. 12th St.)	Cook Chicago (435 W. 12th St.)	Cook Chicago (Randolph & Desplaines Sts.)	Cook Chicago (Canal & 15th Sts.)	Cook Chicago (21st & Racine Sts.
Crane & Co. Well No. 1	Crane & Co. Well No. 2	Crane & Co.	Crane & Co.	Dernier & Co.
290	250	235	415	250
107±	107	To bed rock	To bed rock	To bed rock
18	18	75	18	10
Aug. 25, 1914	Aug. 25, 1914	Aug. 25, 1914	Aug. 25, 1914	......

(parts per million)

40.	48.	40.	32.	76.
.6	.6	32.	.4	.4
.8	1.	2.4	.64	.56
3.5	4.42	10.6	2.80	2.50
27.	12.00	50.	24.	15.
10.3	25.5	29.6	16.	126.7
271.	270.	443.	250.	467.
180.	204.	232.	169.	251.
—62.	—36.	—132.	—50.	48.
1.76	.75	1.92	2.01	3.18

(parts per million)

4.8	6.1	14.5	3.8	3.4
44.6	19.8	82.5	39.6	24.8
15.2	37.7	43.8	23.7	119.4
65.7	38.2	139.9	53.	......
......	......	......	......	57.6
33.6	40.3	33.6	26.9	23.5
......	......	......	......	......
78.	120.	60.	87.	223.
1.2	1.2	66.3	.8	.8
27.9	6.7	2.4	15.2	14.5
271.	270.	443.	250.	467.

(parts per U. S. gallon)

.28	.36	.85	.22	.20
2.60	1.15	4.81	2.31	1.45
.89	2.20	2.55	1.38	6.96
3.83	2.23	8.16	3.09	......
......	......	......	......	3.36
1.96	2.35	1.96	1.57	1.37
......	......	......	......	......
4.55	7.00	3.50	5.07	13.01
.07	.07	3.87	.05	.05
1.63	.39	.14	.89	.85
15.81	15.75	25.84	14.58	27.25

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (Oakwood & Drexel Blvd.)	Chicago (Cottage Grove & 139th Sts.)	Chicago (N. Union & Eagle Ave.)
Owner	Drexel Arms Hotel	Drexel Cafe	Durand & Casper
Depth of well ... feet	185	450?	239
Depth of casing ... feet	To bed rock	To bed rock	103
Rate of pumping ... gals. per min.	8	20	15
Date sample was collected	Aug. 28, 1914	Aug. 29, 1914	Aug. 15, 1914

Determinations made

Magnesium (as $CaCO_3$)	12.	12.	84.
Iron	.1	.4	.0
Nitrate nitrogen	.16	.00	.00
Nitrate	.71	.00	.00
Chlorine	19.	23.	33.
Sulphate	12.3	8.6	39.5
Residue	155.	180.	316.
Alkalinity (as $CaCO_3$)	101.	113.	180.
Non-carbonate hardness (as $CaCO_3$)	—34.	—50.	—52.
Hydrogen sulphide	2.02	1.53	4.72

Hypothetical combinations

Sodium nitrate	1.	......	......
Sodium chloride	31.4	37.9	54.5
Sodium sulphate	18.2	12.7	58.4
Sodium carbonate	36.	53.	55.1
Magnesium sulphate	......	......	......
Magnesium carbonate	10.1	10.1	70.6
Calcium sulphate	......	......	......
Calcium carbonate	55.	51.	44.
Iron carbonate	.2	.8	......
Undetermined	3.1	14.5	33.4
Total	155.	180.	316.

Hypothetical combinations

Sodium nitrate	.06	......	......
Sodium chloride	1.83	2.21	3.17
Sodium sulphate	1.06	.74	3.41
Sodium carbonate	2.10	3.09	3.21
Magnesium sulphate	......	......	......
Magnesium carbonate	.59	.59	4.11
Calcium sulphate	......	......	......
Calcium carbonate	3.21	2.97	2.56
Iron carbonate	.01	.05	......
Undetermined	.18	.85	1.95
Total	9.04	10.50	18.41

waters in northeastern Illinois—Continued

Cook Chicago (1300 Carroll Ave.) B. A. Eckhart Milling Co.	Cook Chicago (Franklin & Superior Sts.) Farley Candy Co.	Cook Chicago (Adams & Market Sts.) J. V. Farwell Co.	Cook Chicago (Stony Island & S. Chicago Ave.) Grand Crossing Tack Co.	Cook Chicago (Willow & Larrabee Sts.) Hetzel Packing Co.
156	336	200	302	160
101	131	105	79	To bed rock
30	50±	6	25	18
Aug. 28, 1914	Aug. 27, 1914	Aug. 28, 1914	July 3, 1914	Aug. 6, 1914

(parts per million)

44.	28.	44.	72.	116.
.0	.0	2.6	.0	.4
.00	.00	......	.56	.00
.00	.00	......	2.5	.00
5.	33.	26.	30.	28.
31.3	Trace	21.4	0.	18.1
179.	221.	228.	208.	296.
128.	154.	137.	139.	201.
6.	—72.	—34.	—58.	—78
.339	1.44	.98	.87	.595

(parts per million)

......	......	......	3.4	......
8.3	54.5	42.9	49.5	46.2
37.7	......	31.6	......	26.8
......	76.3	36.	61.5	82.7
7.2	......	......	......	......
31.9	23.5	37.	60.5	97.4
......	......	......	......	......
90.	54.	59.	9.	7.
......	......	5.4	......	.8
3.9	12.7	16.1	24.1	35.1
179.	221.	228.	208.	296.

(parts per U. S. gallon)

......	......	......	.20	......
.48	3.18	2.50	2.89	2.69
2.20	......	1.84	......	1.56
......	4.45	2.10	3.59	4.82
.42	......	......	......	......
1.86	1.37	2.16	3.53	5.67
......	......	......	......	......
5.25	3.15	3.44	.52	.41
......	......	.31	......	.05
.23	.74	.94	1.41	2.05
10.44	12.89	13.29	12.14	17.25

Table II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (1617 21st Place)	Chicago (100th St. & Calumet River)	Chicago (LaSalle & 25th Sts.)
Owner	Hoerbers Brewery	Lehigh Valley Coal Sales Co.	Miller & Hart
Depth of well ... feet	350±	365	300
Depth of casing ... feet	To bed rock	67	60
Rate of pumping ... gals. per min.	36	15	12
Date sample was collected	Aug. 25, 1914	Aug. 7, 1914	Aug. 27, 1914

Determinations made

Magnesium (as $CaCO_3$)	284.	12.	184.
Iron	.4	.4	.2
Nitrate nitrogen	.80	.00	.00
Nitrate	3.50	.00	.00
Chlorine	15.	30.	11.
Sulphate	402.8	0.	240.
Residue	840.	272.	601.
Alkalinity (as $CaCO_3$)	212.	181.	244.
Non-carbonate hardness (as $CaCO_3$)	320.	—172.	178.
Hydrogen sulphide	2.24	.629	1.96

Hypothetical combinations

Sodium nitrate	4.8	......	......
Sodium chloride	24.8	49.5	18.2
Sodium sulphate	142.3	......	102.8
Sodium carbonate	......	182.3	......
Magnesium sulphate	340.8	......	213.6
Magnesium carbonate	......	10.1	5.
Calcium sulphate	49.	......	......
Calcium carbonate	212.	......	238.
Iron carbonate	.8	.8	.4
Undetermined	65.5	29.3	23.
Total	840.	272.	601.

Hypothetical combinations

Sodium nitrate	.28	......	......
Sodium chloride	1.45	2.88	1.06
Sodium sulphate	8.30	......	5.99
Sodium carbonate	......	10.63	......
Magnesium sulphate	19.88	......	12.45
Magnesium carbonate	......	.59	.29
Calcium sulphate	2.86	......	......
Calcium carbonate	12.37	......	13.88
Iron carbonate	.05	.05	.02
Undetermined	3.82	1.71	1.34
Total	49.01	15.86	35.03

waters in northeastern Illinois—Continued

Cook	Cook	Cook	Cook	Cook
Chicago (210 N. Halsted St.)	Chicago (2608 Arthington St.)	Chicago (113 N. Carpenter St.)	Chicago (98th St. & Calumet River)	Chicago (104th St. & Calumet River)
Morse Chocolate Co.	Murray & Nickels	National Biscuit Co.	Norris & Co.	Rialto Elevator Co.
350±	286	300	346	401
To bed rock	To bed rock	94	85	45
25±	30	10	30	15
Aug. 15, 1914	Aug. 28, 1914	Aug. 28, 1914	Aug. 18, 1914	Aug. 7, 1914

(parts per million)

84.	44.	32.	32.	52.
.2	.1	.0	.2	.3
.08	.00	.00	.00	1.12
.35	.00	.00	.00	4.96
19.	31.	16.	30.	30.
17.7	52.3	34.1	13.	0.
255.	290.	228.	296.	257.
180.	154.	140.	199.	162.
—52.	—16.	—42.	—170.	—146.
.55	.58	1.53	.55	.24

(parts per million)

.5	......	......	......	6.8
31.4	51.2	26.4	49.5	49.5
26.2	77.4	50.5	19.2	......
55.1	17.	44.5	180.2	154.8
......	......	......	......	......
70.6	37.	26.9	26.9	43.7
......	......	......	......	......
44.	94.	66.	......	......
.4	.2	......	.4	.7
26.8	13.2	13.7	19.8	1.5
255.	290.	228.	296.	257.

(parts per U. S. gallon.)

.03	......	......	......	.40
1.83	2.98	1.54	2.87	2.86
1.53	4.51	2.95	1.12	......
3.21	.99	2.60	10.51	9.03
......	......	......	......	......
4.12	2.16	1.57	1.57	2.54
......	......	......	......	......
2.57	5.48	3.85	......	......
.02	.01	......	.02	.04
1.56	.77	.80	1.15	.09
14.87	16.90	13.31	17.24	14.96

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (102nd St. & Calumet River)	Chicago (102nd St. & Calumet River)	Chicago (93rd St. & Harbor Ave.)
Owner	J. Rosenbaum Grain Co.	J. Rosenbaum Grain Co.	South Chicago Elevator Co.
Depth of well feet	350	502	367
Depth of casing feet	To bed rock	65	95
Rate of pumping gals. per min.	18	7±	30
Date sample was collected	Aug. 7, 1914	Aug. 7, 1914	June 26, 1914

Determinations made

Magnesium (as $CaCO_3$)	92.	4.	12.
Iron	.1	.2	.1
Nitrate nitrogen	.6	.32	.08
Nitrate	2.65	1.41	.40
Chlorine	24.	18.	18.
Sulphate	6.6	2.9	0.
Residue	320.	253.	247.
Alkalinity (as $CaCO_3$)	160.	199.	202.
Non-carbonate hardness (as $CaCO_3$)	—138.	—186.	—182.
Hydrogen sulphide	.45	......	.71

Hypothetical combinations

Sodium nitrate	3.6	1.9	.5
Sodium chloride	39.6	29.7	29.7
Sodium sulphate	9.8	4.3	......
Sodium carbonate	146.3	197.2	192.9
Magnesium sulphate	......	......	......
Magnesium carbonate	77.3	3.4	10.1
Calcium sulphate	......	......	......
Calcium carbonate	......	9.	8.
Iron carbonate	.2	.4	.2
Undetermined	43.2	7.1	5.6
Total	320.	253.	247.

Hypothetical combinations

Sodium nitrate	.20	.11	.03
Sodium chloride	2.31	1.73	1.73
Sodium sulphate	.57	.25	......
Sodium carbonate	8.53	11.50	11.25
Magnesium sulphate	......	......	......
Magnesium carbonate	4.51	.20	.59
Calcium sulphate	......	......	......
Calcium carbonate	......	.52	.47
Iron carbonate	.01	.02	.01
Undetermined	2.51	.41	.33
Total	18.64	14.74	14.41

waters in northeastern Illinois—Continued

Cook	Cook	Cook	Cook	Cook
Chicago	Chicago	Chicago	Chicago	Chicago
(93rd St. & Harbor Ave.)	(104th St. & Calumet River)	(98th St. & Baltimore Ave.)	(3914 Ellis Ave.)	(106th St. & Torrence Ave.)
South Chicago Elevator Co.	Star & Crescent Milling Co.	Willard Sons & Bell	Winamar Apartment	Wisconsin Steel Co.
347	340	187	400	405
95	185	105	To bed rock	72
25	15	15	20	20
Aug. 18, 1914	Aug. 7, 1914	Aug. 18, 1914	Aug. 29, 1914	Aug. 7, 1914

(parts per million)

36.	64.	36.	24.	84.
.1	.2	.2	.4	.2
.00	.00	.00	.32	.56
.00	.00	.00	1.41	2.48
38.	22.	17.	21.	24.
5.8	.0	6.	17.7	26.3
294.	232.	255.	178.	292.
200.	167.	187.	110.	202.
—148.	—126.	—170.	—34.	—154.
.54	.48	.52	.88	1.75

(parts per million)

......	......	......	1.9	3.4
62.7	36.3	28.1	34.7	39.6
8.6	......	......	26.2	39.
156.9	133.6	180.2	36.	154.8
......	......	......	......	......
30.2	53.8	30.2	20.2	23.5
......	......	......	......	......
16.	......	......	52.	28.
.2	.4	.4	.8	.4
19.4	7.9	16.1	6.2	3.3
294.	232.	255.	178.	292.

(parts per U. S. gallon)

......	......	......	.11	.20
3.65	2.11	1.64	2.02	2.32
.50	......	......	1.53	2.28
9.15	7.77	10.51	2.10	9.01
......	......	......	......	......
1.76	3.13	1.76	1.18	1.37
......	......	......	......	......
.93	......	......	3.03	1.63
.01	.02	.02	.05	.02
1.13	.46	.94	.36	.19
17.13	13.49	14.87	10.38	17.02

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (601 W. Lake St.)	Chicago (Peoria & Fulton Sts.)	Chicago (4501 Cortland St.)
Owner	L. Wolff Mfg. Co.	Wolff, Sayre & Heller	Acme Malting Co.
Depth of well . . . feet	303	400	1350±
Depth of casing . . . feet	113	To bed rock	To bed rock
Rate of pumping . . . gals. per min.	15	12	50
Date sample was collected	Aug. 15, 1914	Aug. 15, 1914	Aug. 14, 1914

Determinations made

Magnesium (as $CaCO_3$)	116.	64.	48.
Iron	.4	.6	.4
Nitrate nitrogen	.60	.08	.36
Nitrate	2.65	.35	1.60
Chlorine	20.	15.	30.
Sulphate	21.4	10.3	134.1
Residue	327.	212.	394.
Alkalinity (as $CaCO_3$)	244.	161.	150.
Non-carbonate hardness (as $CaCO_3$)	—44.	—52.	8.
Hydrogen sulphide	.84	.39	4.96

Hypothetical combinations

Sodium nitrate	3.6	.5	2.2
Sodium chloride	33.	24.8	49.5
Sodium sulphate	31.6	15.2	187.
Sodium carbonate	46.6	55.1	......
Magnesium sulphate	......	......	9.6
Magnesium carbonate	97.4	53.8	33.6
Calcium sulphate	......	......	......
Calcium carbonate	84.	45.	110.
Iron carbonate	.8	1.2	.8
Undetermined	30.	16.4	1.3
Total	327.	212.	394.

Hypothetical combinations

Sodium nitrate	.21	.03	.13
Sodium chloride	1.92	1.45	2.88
Sodium sulphate	1.84	.88	10.91
Sodium carbonate	2.72	3.21	......
Magnesium sulphate	......	......	.56
Magnesium carbonate	5.68	3.14	1.96
Calcium sulphate	......	......	......
Calcium carbonate	4.90	2.62	6.42
Iron carbonate	.05	.07	.05
Undetermined	1.75	.96	.08
Total	19.07	12.36	22.99

waters in northeastern Illinois—Continued

Cook Chicago (Clybourn & Wrightwood Ave.) American Bridge Co. 1650 To bed rock 45 Jan. 6, 1914	Cook Chicago (1151 Racine Ave.) American Color-type Co. 1580 85 35 Dec. 23, 1913	Cook Chicago (538 Sebor St.) American Express Co. 788 To bed rock 15 Aug. 6, 1914	Cook Chicago (123rd St. & C. & W. I. R. R.) American Malting Co. 1656 68 60 June 6, 1914	Cook Chicago (123rd St. & C. & W. I. R. R) American Malting Co. 1663 68 200 June 6, 1914

(parts per million)

112.	32.	168.	164.	156.
.6	.8	1.2	......	......
.00	.20	.00	.28	.48
.00	.90	.00	1.20	2.20
76.	28.	58.	200.	170.
409.	55.6	244.4	685.9	667.4
961.	308.	691.	1518.	1466.
216.	162.	232.	206.	196.
252.	—12.	90.	452.	432.
......	......	.76	......	......

(parts per million)

......	1.5	......	1.6	3.
125.4	46.2	95.7	330.	280.5
248.	82.3	234.4	371.3	374.4
......	12.7	......	......	......
134.4	......	108.	196.8	187.2
......	26.9	65.5	......	......
190.4	......	......	391.7	375.4
216.	118.	154.	206.	196.
1.2	1.7	2.5	......	......
45.8	18.7	30.9	20.	49.5
961.2	308.	691.	1517.4	1466.

(parts per U. S. gallon)

......	.09	......	.09	.17
7.31	2.69	5.58	19.25	16.35
14.47	4.80	13.66	21.65	21.83
......	.74	......	......	......
7.83	......	6.30	11.48	10.92
......	1.57	3.82	......	......
11.10	......	......	22.83	21.89
12.60	6.88	8.98	12.01	11.43
.07	.10	.14	......	......
2.66	1.09	1.80	1.17	2.86
56.04	17.96	40.28	88.48	85.45

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (123rd St. & C. & W. I. R. R.)	Chicago (123rd St. & C. & W. I. R. R.)	Chicago (123rd St. & C. & W. I. R. R.)
Owner	American Malting Co.	American Malting Co.	American Malting Co.
Depth of well.....feet	1015 (Drilling)	1225 (Drilling)	1315 (Drilling)
Depth of casing.....feet	68	68	68
Rate of pumping.....gals. per min.	......	......	......
Date sample was collected	June 26, 1914	July 20, 1914	Aug. 3, 1914

Determinations made

Magnesium (as $CaCO_3$)	68.	64.	112.
Iron	3.2	.8	.2
Nitrate nitrogen	.00	.40	.00
Nitrate	.00	1.80	.00
Chlorine	80.	66.	46.
Sulphate	30.9	37.9	19.3
Residue	410.	409.	365.
Alkalinity (as $CaCO_3$)	223.	231.	221.
Non-carbonate hardness (as $CaCO_3$)	—158.	—140.	—142.
Hydrogen sulphide	......	......	......

Hypothetical combinations

Sodium nitrate	......	2.5	......
Sodium chloride	132.	108.9	75.9
Sodium sulphate	45.7	56.1	28.6
Sodium carbonate	167.5	148.4	150.5
Magnesium sulphate	......	......	......
Magnesium carbonate	57.1	53.8	94.1
Calcium sulphate	......	......	......
Calcium carbonate	......	27.	......
Iron carbonate	6.6	1.7	.4
Undetermined	1.1	10.6	15.5
Total	410.	409.	365.

Hypothetical combinations

Sodium nitrate	......	.15	......
Sodium chloride	7.70	6.35	4.42
Sodium sulphate	2.66	3.27	1.66
Sodium carbonate	9.77	8.66	8.77
Magnesium sulphate	......	......	......
Magnesium carbonate	3.33	3.14	5.49
Calcium sulphate	......	......	......
Calcium carbonate	......	1.57	......
Iron carbonate	.38	.10	.02
Undetermined	.06	.62	.90
Total	23.90	23.86	21.26

waters in northeastern Illinois—Continued

Cook	Cook	Cook	Cook	Cook
Chicago	Chicago	Chicago	Chicago	Chicago
(123rd St. & C. & W. I. R. R.)	(123rd St. & C. & W. I. R. R.)	(1249 S. Talman Ave.)	(Hickory & Bliss Sts.)	(31st Place & Waterville)
American Malting Co.	American Malting Co.	American Malting Co.	American Malting Co.	Armour Glue Works
1475 (Drilling)	1575 (Drilling)	1603	1302	1595
68	68	571	75	45
......	......	150	110	150
Aug. 8, 1914	Aug. 19, 1914	Jan. 12, 1914	Jan. 8, 1914	Aug. 31, 1914

(parts per million)

160.	40.	144.	204.	116.
.3	.4	.6	.0	.6
.00	.80	.00	.00	.00
.00	3.5	.00	.00	.00
44.	15.	160.	184.	170.
42.8	51.8	489.2	638.6	508.6
422.	231.	1218.	1424.	1260.
255.	126.	228.	220.	209.
—180.	18.	344.	368.	152.
......	......	......	.17	......

(parts per million)

......	4.8	......	......	......
72.6	24.8	264.	303.6	280.5
63.2	51.	236.	423.4	537.2
186.6	......	......	......	......
......	21.6	172.8	244.8	139.2
63.8	52.1	......	......	......
......	......	272.	223.	49.
3.	64.	228.	220.	209.
.6	.8	1.2	......	1.2
32.2	11.9	44.	9.2	43.9
422.	231.	1218.	1424.	1260.

(parts per U. S. gallon)

......	.28	......	......	......
4.23	1.45	15.40	17.70	16.36
3.68	2.97	13.77	24.68	31.33
10.88	......	......	......	......
......	1.26	10.08	14.28	8.12
3.71	3.04	......	......	......
......	......	15.87	13.01	2.86
.17	3.73	13.30	12.83	12.19
.03	.05	.07	......	.08
1.29	.69	2.57	.54	2.56
23.99	13.47	71.06	83.04	73.50

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (31st Place & Waterville)	Chicago (31st Place & Waterville)	Chicago (660 W. Randolph St.)
Owner	Armour Glue Works Butcher Shop	Armour Glue Works Cook House	Arnold Packing Co.
Depth of well ... feet	1210	1500±	1660
Depth of casing ... feet	45	45	To bed rock
Rate of pumping ... gals. per min.	175	150	80
Date sample was collected	Aug. 31, 1914	Aug. 31, 1914	Aug. 15, 1914

Determinations made

Magnesium (as $CaCO_3$)	116.	72.	152.
Iron	.2	.2	.3
Nitrate nitrogen	.56	.72	.00
Nitrate	2.5	3.18	.00
Chlorine	410.	280.	90.
Sulphate	391.7	439.9	489.2
Residue	1489.	1347.	1108.
Alkalinity (as $CaCO_3$)	221.	221.	230.
Non-carbonate hardness (as $CaCO_3$)	132.	138.	316.
Hydrogen sulphide	......	......	.32

Hypothetical combinations

Sodium nitrate	3.4	4.4	......
Sodium chloride	676.6	462.1	148.5
Sodium sulphate	392.6	455.1	275.8
Sodium carbonate	......	......	......
Magnesium sulphate	139.2	86.4	182.4
Magnesium carbonate	......	......	......
Calcium sulphate	21.8	89.8	182.4
Calcium carbonate	221.	221.	230.
Iron carbonate	.4	.4	.6
Undetermined	34.	27.8	88.3
Total	1489.	1347.	1108.

Hypothetical combinations

Sodium nitrate	.20	.26	......
Sodium chloride	39.47	26.94	8.66
Sodium sulphate	22.90	26.57	16.09
Sodium carbonate	......	......	......
Magnesium sulphate	8.11	5.04	10.64
Magnesium carbonate	......	......	......
Calcium sulphate	1.27	5.24	10.64
Calcium carbonate	12.89	12.89	13.42
Iron carbonate	.02	.02	.03
Undetermined	1.98	1.62	5.14
Total	86.84	78.58	64.62

waters in northeastern Illinois—Continued

Cook Chicago 918 W. 12th St.) Bartholomae & Roesing	Cook Chicago (1317 Fletcher St.) Best Brewery Co.	Cook Chicago (1315 Webster Ave.) Birk Bros. Brewery	Cook Chicago (1616 Burlington St.) Bishop & Babcock	Cook Chicago (Kinzie & Clark Sts.) Booth Cold Storage Co.
1609	2013	1610	1600±	926
85	64	40	73	79
50	117	45	100	35
Jan. 12, 1914	Dec. 23, 1913	Dec. 23, 1913	Sept. 5, 1914	Aug. 6, 1914

(parts per million)

124.	100.	148.	112.	64.
1.2	.8	0.	.1	.2
.00	.20	.08	.00	.00
.00	.90	.40	.00	00.
64.	162.	80.	95.	36.
360.4	849.7	530.8	330.8	8.2
758.	1740.	1146.	860.	324.
130.	212.	216.	207.	217.
256.	176.	352.	260.	—76.
.18	......	......	......	.55

(parts per million)

......	1.5	.5	......	......
105.6	267.3	132.	156.8	59.4
170.	1006.3	286.1	120.6	12.1
......	......	......	......	80.6
148.8	120.	177.6	134.4	......
......	......	......	......	53.8
179.5	103.4	277.4	201.3	......
130.	212.	216.	207.	77.
2.5	1.7	......	.2	.4
21.6	27.8	56.4	39.7	40.7
758.	1740.	1146.	860.	324.

(parts per U. S. gallon)

......	.09	.03	......	......
6.15	15.57	7.70	9.15	3.46
9.92	58.69	16.68	7.03	.71
......	......	......	......	4.70
8.67	7.00	10.35	7.84	......
......	......	......	......	3.13
10.49	6.03	16.17	11.74	......
7.58	12.37	12.60	12.07	4.49
.15	.10	......	.01	.02
1.30	1.62	3.28	2.32	2.37
44.26	101.47	66.81	50.16	18.88

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (Elston & Snow Sts.)	Chicago (2530 Elston Ave.)	Chicago (120 W. Madison St.)
Owner	Brand Branch U. S. Brewing	Brand Brewing Co.	Brevoort Hotel
Depth of well .... feet	1346	1600±	1280
Depth of casing .... feet	60	60	To bed rock
Rate of pumping .... gals. per min.	75	125	50
Date sample was collected	Dec. 23, 1913	Dec. 23, 1913	June 23, 1914

Determinations made

Magnesium (as $CaCO_3$)	104.	180.	140.
Iron	1.2	.0	.7
Nitrate nitrogen	.24	.00	.40
Nitrate	1.1	.00	1.80
Chlorine	40.	100.	130.
Sulphate	227.3	535.7	518.
Residue	588.	1174.	1247.
Alkalinity (as $CaCO_3$)	160.	220.	236.
Non-carbonate hardness (as $CaCO_3$)	116.	320.	392.
Hydrogen sulphide	......	......	......

Hypothetical combinations

Sodium nitrate	1.5	......	2.5
Sodium chloride	66.	165.1	214.5
Sodium sulphate	171.7	339.	352.5
Sodium carbonate	......	......	......
Magnesium sulphate	125.	216.	158.
Magnesium carbonate	......	......	......
Calcium sulphate	16.3	190.4	206.7
Calcium carbonate	160.	220.	236.
Iron carbonate	2.5	......	1.5
Undetermined	45.	43.5	65.3
Total	588.	1174.	1247.

Hypothetical combinations

Sodium nitrate	.09	......	.15
Sodium chloride	3.84	9.63	12.49
Sodium sulphate	10.01	19.77	20.54
Sodium carbonate	......	......	......
Magnesium sulphate	7.29	12.60	9.80
Magnesium carbonate	......	......	......
Calcium sulphate	.95	11.10	12.04
Calcium carbonate	9.33	12.83	13.77
Iron carbonate	.15	......	.09
Undetermined	2.62	2.54	3.80
Total	34.28	68.47	72.68

waters in northeastern Illinois—Continued

Cook Chicago (1263 W. North Ave.) Chicago Brewery	Cook Chicago (1632 Indiana Ave.) Chicago Cold Storage Co.	Cook Chicago (1632 Indiana Ave.) Chicago Cold Storage Co.	Cook Chicago (4535 Gross Ave.) Chicago Packing Co.	Cook Chicago (Archer Ave. & Throop St.) Citizens Brewery
1875	1000 (Drilling)	1117 (Drilling)	1615	2188
90	......	......	400	100
75	To bed rock	To bed rock	83	To bed rock
Jan. 8, 1914	June 10, 1914	June 24, 1914	July 20, 1914	Sept. 5, 1914

(parts per million)

88.	144.	276.	160.	176.
1.4	.2	.4	.3	1.5
.00	.48	.08	.56	.00
.00	2.20	.40	2.50	.00
136.	21.	50.	115.	1800.
539.	25.5	16.5	531.6	253.9
1293.	438.	548.	1164.	3717.
208.	364.	480.	209.	197.
156.	—104.	—72.	370.	568.
......	......	......	.51	......

(parts per million)

......	3.	.5	3.4	......
224.4	34.7	82.5	189.8	2614.6
576.4	37.7	24.4	272.2	......
......	110.2	76.3	......	......
105.6	......	......	192.	211.2
......	121.	231.8	......	......
92.5	......	......	275.6	121.1
208.	116.	132.	209.	197.
2.9	.4	.8	.6	3.1
38.2	15.	......	21.4	232.9
1293.	438.	548.3	1164.	3717.

(parts per U. S. gallon)

......	.17	.03	.20	......
13.08	2.02	4.8	11.07	152.51
33.61	2.20	1.42	15.88	......
......	6.42	4.45	......	......
6.15	......	......	11.20	12.32
......	7.06	13.51	......	......
5.39	......	......	16.07	7.06
12.13	6.77	7.69	12.19	11.49
.17	.02	.05	.03	.18
2.23	.87	......	1.25	13.58
75.38	25.53	31.95	67.89	216.80

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (61st & University Ave.)	Chicago (65th St. & Lowe Ave.)	Chicago (30 N. Green St.)
Owner	Consumers Ice Co.	Consumers Ice Co.	Cooke Brewery
Depth of well.........feet	1967	1700	1800
Depth of casing.........feet	To bed rock	To bed rock	To bed rock
Rate of pumping.........gals. per min.	300	135	85
Date sample was collected	Dec. 18, 1913	June 23, 1914	Jan. 13, 1914

Determinations made

Magnesium (as $CaCO_3$)	184.	124.	120.
Iron	.4	.0	1.4
Nitrate nitrogen	.8	.08	.52
Nitrate	3.50	.40	2.30
Chlorine	230.	140.	500.
Sulphate	705.6	334.1	783.4
Residue	1607.	1000.	2146.
Alkalinity (as $CaCO_3$)	214.	216.	228.
Non-carbonate hardness (as $CaCO_3$)	482.	236.	144.
Hydrogen sulphide	.14	......	.31

Hypothetical combinations

Sodium nitrate	4.8	.5	3.2
Sodium chloride	379.5	231.	740.
Sodium sulphate	360.3	159.5	955.4
Sodium carbonate	......	......	......
Magnesium sulphate	220.8	148.8	144.
Magnesium carbonate	......	......	......
Calcium sulphate	405.3	152.3	32.6
Calcium carbonate	214.	216.	228.
Iron carbonate	.8	......	2.9
Undetermined	21.5	91.9	39.9
Total	1607.	1000.	2146.

Hypothetical combinations

Sodium nitrate	.28	.03	.19
Sodium chloride	22.13	13.47	43.16
Sodium sulphate	21.02	9.30	55.72
Sodium carbonate	......	......	......
Magnesium sulphate	12.88	8.67	8.40
Magnesium carbonate	......	......	......
Calcium sulphate	23.67	8.88	1.90
Calcium carbonate	12.48	12.60	13.30
Iron carbonate	.05	......	.17
Undetermined	1.25	5.35	2.33
Total	93.76	58.30	125.17

waters in northeastern Illinois—Continued

Cook	Cook	Cook	Cook	Cook
Chicago	Chicago	Chicago	Chicago	Chicago
(1461 Clybourn Ave.)	(42nd St. & Ashland Ave.)	(44th St. & Cook Ave.)	(1734 Fullerton Ave.)	(1734 Fullerton Ave.)
Crystal Ice Mfg. Co.	Darling Packing Co.	Darling Packing Co.	Deering Branch International Harvester Co.	Deering Branch International Harvester Co.
1614	1300	1683	1568	1500
92	66	61	37	37
175	300	150	110	40
June 5, 1914	July 20, 1914	Sept. 3, 1914	Dec. 23, 1913	Dec. 23, 1913

(parts per million)

164.	132.	120.	148.	144.
.0	.10	.2	1.2	.8
.00	.36	.52	.08	.20
.00	1.60	3.08	.40	.9
130.	134.	425.	226.	100.
580.4	441.9	476.5	571.9	505.7
1278.	1087.	1691.	1418.	1134.
226.	211.	207.	220.	212.
408.	302.	402.	392.	320.
......	.26	.37	......	......

(parts per million)

......	2.2	4.2	.5	1.2
214.5	221.1	701.3	372.9	165.
280.3	224.9	135.4	291.4	294.4
......	......	......	......	......
196.8	158.4	144.	177.6	172.8
......	......	......	......	......
331.8	231.2	383.5	331.8	239.4
226.	211.	207.	220.	212.
......	.2	.4	2.5	1.7
28.6	38.	115.2	21.3	47.5
1278.	1087.	1691.	1418.	1134.

(parts per U. S. gallon)

......	.13	.24	.03	.07
12.50	12.90	40.90	21.75	9.62
16.35	13.12	7.90	16.99	17.17
......	......	......	......	......
11.47	9.42	8.40	10.35	10.08
......	......	......	......	......
19.34	13.49	22.37	19.36	13.96
13.18	12.31	12.07	12.83	12.37
......	.01	.02	.15	.10
1.67	2.22	6.72	1.24	2.77
74.51	63.42	98.62	82.70	66.14

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (Robinson St. & Ill. Mich. Canal)	Chicago (2610 N. Western Ave.)	Chicago (51st St. & Pennsylvania R. R.)
Owner	Diamond Glue Works	Eagle Brewery	Fleishman Malting Co.
Depth of well, feet	1950	1583	750±
Depth of casing, feet	To bed rock	To bed rock	To bed rock
Rate of pumping, gals. per min.	50	100	20
Date sample was collected	Aug. 24, 1914	Jan. 6, 1914	Aug. 29, 1914

Determinations made

Magnesium (as $CaCO_3$)	132.	156.	40.
Iron	.8	.0	.6
Nitrate nitrogen	1.00	.00	.00
Nitrate	4.42	.00	.00
Chlorine	97.	84.	27.
Sulphate	549.3	484.7	16.
Residue	1186.	1100.	199.
Alkalinity (as $CaCO_3$)	179.	232.	132.
Non-carbonate hardness (as $CaCO_3$)	360.	200.	—26.
Hydrogen sulphide	......	......	......

Hypothetical combinations

Sodium nitrate	6.1	......	......
Sodium chloride	160.1	138.6	44.6
Sodium sulphate	313.3	433.8	23.7
Sodium carbonate	......	......	27.6
Magnesium sulphate	158.4	187.2	......
Magnesium carbonate	......	......	33.6
Calcium sulphate	310.1	59.8	......
Calcium carbonate	179.	232.	66.
Iron carbonate	1.7	1.2	1.2
Undetermined	57.3	47.4	2.3
Total	1186.	1100.	199.

Hypothetical combinations

Sodium nitrate	.36	......	......
Sodium chloride	9.34	8.07	2.60
Sodium sulphate	18.28	25.30	1.38
Sodium carbonate	......	......	1.61
Magnesium sulphate	9.24	10.91	......
Magnesium carbonate	......	......	1.96
Calcium sulphate	18.08	3.49	......
Calcium carbonate	10.44	13.53	3.85
Iron carbonate	.10	.07	.07
Undetermined	3.34	2.76	.13
Total	69.18	64.13	11.60

waters in northeastern Illinois—Continued

Cook Chicago (412 S. Desplaines St.)	Cook Chicago (Fulton & Green Sts.)	Cook Chicago (21st Place & Albany Ave.)	Cook Chicago (337 Alexander St.)	Cook Chicago (79th St. & Stony Island)
Fortune Bros. Brewery	Fulton Wholesale Market	Garden City Brewery	Gottfried Brewery	Grand Crossing Tack Co.
1679	1350	1410	1658	1630
112	90	To bed rock	76	80
200	45	200+	685	110
Jan. 13, 1914	Jan. 13, 1914	Jan. 9, 1914	Dec. 17, 1913	July 3, 1914

(parts per million)

156.	92.	184.	164.	224.
.8	1.	1.2	.4	.4
.00	.00	.00	.24	.56
.00	.00	.00	1.10	2.5
82.	42.	550.	440.	240.
543.1	125.1	347.3	550.7	696.2
1134.	426.	1640.	1781.	1649.
214.	180.	224.	226.	218.
388.	72.	340.	372.	428.
......	......	......	......	......

(parts per million)

......	......	......	1.5	3.4
135.3	69.3	907.6	726.1	396.1
254.1	83.2	31.5	287.1	423.6
......	......	......	......	......
187.2	86.4	220.8	196.8	268.8
......	16.8	......	......	......
315.5	......	212.2	282.9	277.4
214.	160.	224.	226.	218.
1.6	1.4	2.5	.8	.8
26.3	8.9	41.4	59.8	60.9
1134.	426.	1640.	1781.	1649.

(parts per U. S. gallon)

......	......	......	.09	.2
7.89	4.03	52.93	42.34	23.10
14.82	4.85	1.84	16.75	24.71
......	......	......	......	......
10.92	5.03	12.88	11.48	15.68
......	.98	......	......	......
18.40	......	12.37	16.50	16.18
12.48	9.33	13.06	13.18	12.71
.09	.08	.14	.05	.05
1.53	.52	2.41	3.49	3.55
66.13	24.82	95.63	103.88	96.18

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (445 N. Sacramento Blvd.)	Chicago (1511 Webster)	Chicago (46th St. & RacineAve.)
Owner	Griffen Wheel Co.	Gutman Tanneries	Hammond & Co. East Well
Depth of well....feet	1738	990	1592
Depth of casing....feet	To bed rock	85	67
Rate of pumping....gals. per min.	175	90	100
Date sample was collected	Jan. 11, 1914	Dec. 22, 1913	Sept. 8, 1914

Determinations made

Magnesium (as $CaCO_3$)	212.	164.	152.
Iron	.4	.8	.4
Nitrate nitrogen	.00	.20	.12
Nitrate	.00	.90	.53
Chlorine	210.	82.	155.
Sulphate	564.5	441.9	[illegible]
Residue	1389.	1030.	1436.
Alkalinity (as $CaCO_3$)	218.	230.	209.
Non-carbonate hardness (as $CaCO_3$)	344.	224.	464.
Hydrogen sulphide	......	......	.28

Hypothetical combinations

Sodium nitrate	......	1.2	.7
Sodium chloride	346.5	135.3	255.8
Sodium sulphate	347.3	336.2	269.6
Sodium carbonate	......	......	......
Magnesium sulphate	254.4	196.8	182.4
Magnesium carbonate	......	......	......
Calcium sulphate	179.5	81.6	424.3
Calcium carbonate	218.	230.	209.
Iron carbonate	.8	1.7	.8
Undetermined	42.5	47.2	93.4
Total	1389.	1030.	1436.

Hypothetical combinations

Sodium nitrate	......	.07	.04
Sodium chloride	20.21	7.88	14.92
Sodium sulphate	20.26	19.60	15.72
Sodium carbonate	......	......	......
Magnesium sulphate	14.83	11.47	10.64
Magnesium carbonate	......	......	......
Calcium sulphate	10.47	4.75	24.74
Calcium carbonate	12.72	13.42	12.19
Iron carbonate	.05	.10	.05
Undetermined	2.48	2.75	5.45
Total	81.02	60.04	83.75

waters in northeastern Illinois—Continued

Cook Chicago (46th St. & Racine Ave.) Hammond & Co.	Cook Chicago (46th St. & Racine Ave.) Hammond & Co.	Cook Chicago (North Ave. & Clybourn) Peter Hand Brewery	Cook Chicago (89th St. near Lake Mich.) Illinois Steel Co.	Cook Chicago (48th Ave. & Oakley) Illinios Vinegar Works
Middle Well	West Well			
1592	1592	1972	2080	1689
64	66	80	80	56
100	100	50	16	350
Sept. 8, 1914	Sept. 8, 1914	Dec. 24, 1913	June 26, 1914	Oct. 6, 1915

(parts per million)

132.	128.	72.	104.	128.
.2	.2	.0	3.	1.
.00	.00	.28	.40	.00
.00	.00	1.2	1.8	1.41
130.	180.	206.	887.	164.
598.3	617.2	890.8	104.9	444.
1393.	1518.	1894.	1890.	1177.
204.	202.	214.	270.	235.
444.	—30.	136.	12.	300.
.28	.36	......	......	......

(parts per million)

......	......	1.6	2.5	2.
214.5	297.	339.9	1463.7	271.
255.2	913.4	1125.4	138.2	231.
......	31.8	......	......	......
158.4	......	86.4	14.4	154.
......	107.5	......	77.3	......
424.3	......	87.	......	234.
204.	44.	214.	173.	235.
.4	.4	......	6.2	2.
136.2	123.8	39.7	14.7	48.
1393.	1517.9	1894.	1890.	1177.

(parts per U. S. gallon)

......	......	.09	.15	.12
12.51	17.32	19.82	85.36	15.81
14.88	53.28	65.93	8.06	13.47
......	1.85	......	......	......
9.26	......	5.04	.84	8.98
......	6.27	......	4.51	......
24.74	......	5.07	......	13.65
11.90	2.57	12.48	10.09	13.71
.02	.02	......	.36	.12
7.94	7.22	2.31	.86	2.80
81.25	88.53	110.74	110.23	68.66

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (2612 W. 19th St.)	Chicago (1440 N. Halsted St.)	Chicago (41st St. & Halsted St.)
Owner	Illinois Vinegar Works	Independent Brewery	Independent Packing Co.
Depth of well, feet	1350±	2164	1605
Depth of casing, feet	To bed rock	83	75
Rate of pumping, gals. per min.	150	125	75
Date sample was collected	Jan. 9, 1914	Jan. 6, 1914	Aug. 31, 1914

Determinations made

Magnesium (as $CaCO_3$)	128.	76.	64.
Iron	.6	.8	6.
Nitrate nitrogen	.00	.00	6.
Nitrate	.00	.00	26.5
Chlorine	330.	2.9	270.
Sulphate	332.9	868.6	240.3
Residue	1284.	2019.	1503.
Alkalinity (as $CaCO_3$)	224.	212.	145.
Non-carbonate hardness (as $CaCO_3$)	196.	152.	88.
Hydrogen sulphide	......	......	.82

Hypothetical combinations

Sodium nitrate	......	......	36.3
Sodium chloride	544.6	478.6	445.6
Sodium sulphate	213.2	1069.7	174.
Sodium carbonate	......	......	......
Magnesium sulphate	153.6	91.2	76.8
Magnesium carbonate	......	......	......
Calcium sulphate	92.5	103.4	87.
Calcium carbonate	224.	212.	145.
Iron carbonate	1.2	1.7	12.4
Undetermined	54.9	62.4	......
Total	1284.	2019.	977.1

Hypothetical combinations

Sodium nitrate	......	......	2.12
Sodium chloride	31.79	27.95	25.99
Sodium sulphate	12.43	162.38	10.15
Sodium carbonate	......	......	......
Magnesium sulphate	8.95	5.31	4.48
Magnesium carbonate	......	......	......
Calcium sulphate	5.39	6.02	5.07
Calcium carbonate	13.07	12.37	8.46
Iron carbonate	.07	.10	.72
Undetermined	3.20	3.64	......
Total	74.90	217.77	56.99

waters in northeastern Illinois—Continued

Cook Chicago (31st St. & Rockwell) International Harvester Co. Tractor Works	Cook Chicago (120th St. & Morgan Ave.) International Harvester Co.	Cook Chicago (2320 N. Robey St.) Jefferson Ice Co.	Cook Chicago (Polk St. & Rockwell) Jelke Butterine Co.	Cook Chicago (1735 Diversey Parkway Library Bureau
1660	1246	1525	1640	1099
50	90	To bed rock	To bed rock	To bed rock
100	150	225	175	75
Sept. 26, 1914	June 25, 1914	Jan. 8, 1914	Aug. 27, 1914	Jan. 6, 1914

(parts per million)

140.	152.	200.	120.	120.
1.8	.2	.0	.0	.6
......	.44	.00	.00	.00
6.2	1.8	.00	.00	.00
90.	160.	680.	69.	60.
511.4	432.9	605.7	391.7	240.5
1130.	1224.	2245.	899.	661.
216.	238.	224.	195.	208.
342.	288.	440.	232.	84.
......	......	......	.44	......

(parts per million)

8.5	2.5	......	......	......
148.5	264.	1122.1	113.9	99.
271.4	233.	272.6	250.4	236.9
......	......	......	......	......
168.	182.4	240.	144.	100.8
......	......	......	......	30.2
274.7	185.	326.	152.3	......
216.	238.	224.	195.	172.
3.7	.4	......	......	1.2
39.2	44.7	59.9	43.4	20.9
1130.	1150.	2245.	899.	661.

(parts per U. S. gallon)

.49	.15	......	......	......
8.66	15.40	65.44	6.64	5.77
15.82	13.59	15.90	14.60	13.81
......	......	......	......	......
9.80	10.63	14.00	8.40	5.88
......	......	......	......	1.76
16.02	10.79	19.03	8.88	......
12.60	13.88	13.07	11.37	10.03
.21	.02	......	......	.07
2.28	2.60	3.49	2.53	1.22
65.88	67.06	130.93	52.42	38.54

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago	Chicago	Chicago
Owner	(31st St. & Kedzie Ave.) Liquid Carbonic Co.	(Fullerton & Elston Ave.) J. Lister Glue Works	(Fullerton & Elston Ave.) J. Lister Glue Works
Depth of well ... feet	1610	700	1200
Depth of casing ... feet	62	To bed rock	To bed rock
Rate of pumping ... gals. per min.	150	50	75
Date sample was collected	Aug. 6, 1914	Dec. 23, 1913	Dec. 23, 1913

Determinations made

Magnesium (as $CaCO_3$)	176.	168.	172.
Iron	.2	.0	.8
Nitrate nitrogen	.08	.28	.12
Nitrate	.35	1.20	.50
Chlorine	46.	152.	80.
Sulphate	294.2	495.8	461.2
Residue	648.	1168.	1064.
Alkalinity (as $CaCO_3$)	171.	230.	238.
Non-carbonate hardness (as $CaCO_3$)	186.	292.	240.
Hydrogen sulphide	.17	......	......

Hypothetical combinations

Sodium nitrate	.5	1.6	.7
Sodium chloride	75.9	247.5	132.
Sodium sulphate	170.8	319.5	342.1
Sodium carbonate	......	......	......
Magnesium sulphate	211.2	201.6	206.4
Magnesium carbonate	......	......	......
Calcium sulphate	13.6	168.6	92.5
Calcium carbonate	171.	230.	238.
Iron carbonate	.4	......	1.7
Undetermined	4.6	......	50.6
Total	648.	1168.8	1064.

Hypothetical combinations

Sodium nitrate	.03	.09	.04
Sodium chloride	4.42	14.44	7.70
Sodium sulphate	9.96	18.64	19.95
Sodium carbonate	......	......	......
Magnesium sulphate	12.31	11.75	12.04
Magnesium carbonate	......	......	......
Calcium sulphate	.79	9.83	5.39
Calcium carbonate	9.97	13.42	13.88
Iron carbonate	.02	......	.10
Undetermined	.27	......	2.95
Total	37.77	68.17	62.05

waters in northeastern Illinois—Continued

Cook Chicago (Paulina & Kinzie Sts.) Lomax Bottle Co.	Cook Chicago (3901 Emerald Ave.) Manhattan Brewery	Cook Chicago (Sedgwick & Beethoven Ave.) O. F. Mayer Packing Co.	Cook Chicago (26th St. & Blue Island) McCormick Branch, I. H. Co.	Cook Chicago (27th St. & Western Ave.) McCormick Branch, I. H. Co.
1625	1643	1626	1744	1659
113	811	107	30	50
60	80	100	225	200
Aug. 27, 1914	Jan. 25, 1914	Aug. 6, 1914	Sept. 4, 1914	Sept. 4, 1914

(parts per million)

112.	192.	164.	128.	120.
.0	.7	.2	.1	.1
.00	.64	.00	.00	.68
.00	2.80	.00	.00	3.00
37.	240.	166.	165.	150.
178.	553.4	598.7	380.6	446.
512.	1448.	1387.	1142.	1120.
178.	206.	157.	215.	209.
52.	380.	446.	272.	310.
1.86	......	.66	.....	......

(parts per million)

......	3.8	......	......	4.1
61.1	396.1	273.9	272.3	247.5
189.4	280.	253.9	177.6	220.1
......	......	......	......	......
62.4	230.4	196.8	153.6	144.
50.4	......	......	......	......
......	355.7	383.5	195.8	258.4
118.	206.	157.	215.	209.
......	1.4	.4	.2	.2
30.7	74.6	121.5	127.5	36.7
512.	1448.	1387.	1142.	1120.

(parts per U. S. gallon)

......	.22	......	......	.24
3.56	23.10	15.97	15.88	14.44
11.05	16.33	14.80	10.36	12.84
......	......	......	......	......
3.64	13.44	11.48	8.96	8.40
2.94	......	......	......	......
......	14.91	22.37	11.42	15.07
6.88	12.02	9.16	12.54	12.19
......	.08	.02	.01	.01
1.79	4.35	7.08	7.44	2.14
29.86	84.45	80.88	66.61	65.33

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (2639 Grand Ave.)	Chicago (45th Place & Packers Ave.)	Chicago (2421 W. 21st St.)
Owner	Mechanical Rubber Co.	Miller & Hart Packing Co.	Monarch Brewery
Depth of well feet	1260	1641	1600
Depth of casing feet	To bed rock	174	To bed rock
Rate of pumping gals. per min	65	225	115
Date sample was collected	Aug. 6, 1914	July 21, 1914	Dec. 17, 1913

Determinations made

Magnesium (as $CaCO_3$)	232.	164.	192.
Iron	.2	.2	.0
Nitrate nitrogen	.60	.60	.56
Nitrate	2.65	2.70	2.50
Chlorine	190.	130.	250.
Sulphate	513.1	526.7	412.4
Residue	1291.	1234.	1253.
Alkalinity (as $CaCO_3$)	174.	206.	228.
Non-carbonate hardness (as $CaCO_3$)	300.	380.	292.
Hydrogen sulphide	.24	.25	......

Hypothetical combinations

Sodium nitrate	3.6	3.7	3.4
Sodium chloride	313.5	214.5	412.6
Sodium sulphate	333.	246.2	196.1
Sodium carbonate	......	......	......
Magnesium sulphate	278.4	196.8	230.4
Magnesium carbonate	......	......	......
Calcium sulphate	92.5	293.8	136.
Calcium carbonate	174.	206.	228.
Iron carbonate	.4	.4	......
Undetermined	95.6	72.6	46.5
Total	1291.	1234.	1253.

Hypothetical combinations

Sodium nitrate	20	.22	.19
Sodium chloride	18.28	12.51	24.03
Sodium sulphate	19.42	14.36	11.43
Sodium carbonate	......	......	......
Magnesium sulphate	16.23	11.48	13.44
Magnesium carbonate	......	......	......
Calcium sulphate	5.39	17.14	7.93
Calcium carbonate	10.15	12.02	13.30
Iron carbonate	.02	.02	......
Undetermined	5.57	4.23	2.71
Total	75.26	71.98	73.03

waters in northeastern Illinois—Continued

Cook Chicago (2421 W. 21st St.) Monarch Brewery 1573 To bed rock 400 June 23, 1914	Cook Chicago (Union Stock Yards) Morris & Co. Sec. J, 1260 70 225 July 6, 1914	Cook Chicago (Union Stock Yards) Morris & Co. Sec. 15 1331 To bed rock 275 July 6, 1914	Cook Chicago (Union Stock Yards) Morris & Co. Hog house 2325 To bed rock 250 July 6, 1914	Cook Chicago (Union Stock Yards) Morris & Co. Glue house, 20 1622 67 300 July 6, 1914

(parts per million)

132.	228.	144.	264.	176.
.0	.8	.4	7.	.3
.16	.68	.24	.60	.08
.70	3.00	1.10	2.70	.40
180.	410.	210.	2000.	140.
414.8	431.6	350.6	177.7	416.4
1128.	1563.	1067.	3761.	1060.
214.	203.	197.	186.	231.
304.	412.	292.	450.	284.
......	.32	......	.36	.40

(parts per million)

1.	4.1	1.5	3.7	.5
297.	676.6	346.5	2990.2	231.
182.5	54.5	104.6	......	213.6
......	......	......	......	......
158.4	273.6	172.8	......	211.2
......	......	......	250.8	......
233.9	250.2	201.3	252.9	146.9
214.	203.	197.	173.	231.
......	1.7	.8	14.5	.6
41.2	99.3	42.5	75.9	25.2
1128.	1563.	1067.	3761.	1060.

(parts per U. S. gallon)

.05	.24	.09	.22	.03
17.32	39.47	20.21	174.42	13.47
10.64	3.18	6.10	......	12.46
......	......	......	......	......
9.24	15.96	10.08	......	12.32
......	......	......	14.63	......
13.64	14.59	11.74	14.75	8.57
12.48	11.84	11.49	10.09	13.47
......	.10	.05	.85	.03
2.4	5.79	2.48	4.43	1.47
65.77	91.17	62.24	219.39	61.82

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (Union Stock Yards)	Chicago (3937 Wallace St.)	Chicago (1908 W. 18th St.)
Owner	Morris & Co. Oleo House	Mullens Brewery	National Brewery
Depth of well ... feet	2300±	1632	1590
Depth of casing ... feet	To bed rock	43	18
Rate of pumping ... gals. per min	250	70	100
Date sample was collected	July 22, 1914	Dec. 16, 1913	Dec. 18, 1913

Determinations made

Magnesium (as $CaCO_3$)	444.	108.	156.
Iron	1.	.4	1.6
Nitrate nitrogen	.12	.00	.24
Nitrate	.50	.00	1.10
Chlorine	2800.	120.	130.
Sulphate	337.4	466.1	555.8
Residue	5300.	1088.	1217.
Alkalinity (as $CaCO_3$)	177.	214.	210.
Non-carbonate hardness (as $CaCO_3$)	594.	272.	360.
Hydrogen sulphide	.26	.46	......

Hypothetical combinations

Sodium nitrate	.7	......	1.5
Sodium chloride	4288.	198.	214.5
Sodium sulphate	......	303.4	311.7
Sodium carbonate	......	......	......
Magnesium sulphate	242.6	130.	182.7
Magnesium carbonate	254.2	......	......
Calcium sulphate	204.	223.	277.4
Calcium carbonate	177.	214.	210.
Iron carbonate	2.1	.8	3.3
Undetermined	131.4	18.8	11.4
Total	5300.	1088.	1217.

Hypothetical combinations

Sodium nitrate	.04	......	.03
Sodium chloride	250.12	11.55	12.67
Sodium sulphate	......	17.69	18.55
Sodium carbonate	......	......	......
Magnesium sulphate	14.15	7.58	10.91
Magnesium carbonate	14.83	......	......
Calcium sulphate	11.90	13.01	16.17
Calcium carbonate	10.32	12.48	12.25
Iron carbonate	.12	.05	.19
Undetermined	7.66	1.10	.66
Total	309.14	63.46	71.43

waters in northeastern Illinois—Continued

Cook Chicago (2270 Clybourn Ave.) Northwestern Brewery 1302 To bed rock 40 Dec. 23, 1913	Cook Chicago (Halsted & Lumber St.) Omaha Packing Co. 1300+ 32 200 Aug. 28, 1914	Cook Chicago (3927 S. Halsted St.) Pfaelzer Packing Co. 1600 To bed rock 100 Aug. 29, 1914	Cook Chicago (3249 W. 26th St.) Pilsen Brewery 1845 To bed rock 100 Dec. 18, 1913	Cook Chicago (Lombard Ave. & Gt. W. R. R.) Public Service Co. of N. Ill. 1705 82 100 July 8, 1914

(parts per million)

192.	160.	128.	104.	92.
.00	.0	.6	1.6	.4
.52	.00	.00	.00	.00
2.20	.00	.00	.00	.00
234.	155.	210.	39.	150.
569.9	578.8	511.7	92.2	134.5
1434.	1310.	1343.	375.	664.
202.	207.	219.	152.	233.
356.	374.	354.	36.	2.
......	.21	1.5	......	......

(parts per million)

3.	......	......	......	......
386.1	255.8	346.5	64.4	247.5
338.5	319.7	254.8	85.4	196.2
......	......	......	......	......
230.4	192.	153.6	43.2	2.4
......	......	......	......	75.6
223.	291.	307.4	57.1	......
202.	207.	219.	84.	143.
......	......	1.2	3.3	.8
51.	44.5	60.5	37.6	......
1434.	1310.	1343.	375.	665.5

(parts per U. S. gallon)

.17	......	......	......	......
22.52	14.92	20.21	3.75	14.44
19.74	18.64	14.86	4.98	11.44
......	......	......	......	......
13.44	11.20	8.96	2.52	.14
......	......	......	......	4.41
13.00	16.97	17.93	3.33	......
11.78	12.07	12.77	4.90	8.34
......	......	.07	.19	.05
2.97	2.60	3.53	2.19	......
83.62	76.40	78.33	21.86	38.82

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (Lombard Ave. & Gt. W. R. R.)	Chicago (445 Grant Place)	Chicago (Canalport Ave. & 18th St.)
Owner	Public Service Co. of N. Ill.	Schmidt Brewery	Schoenhoffen Brewery
Depth of well feet	1912	1603	1600
Depth of casing feet	97	To bed rock	75
Rate of pumping gals. per min.	125	35	100
Date sample was collected	July 8, 1914	Jan. 13, 1914	Dec. 18, 1913

Determinations made

Magnesium (as $CaCO_3$)	188.	72.	140.
Iron	.4	.8	2.
Nitrate nitrogen	.00	.72	.00
Nitrate	.00	3.10	.00
Chlorine	185.	28.	120.
Sulphate	209.	37.5	569.1
Residue	873.	283.	1289.
Alkalinity (as $CaCO_3$)	262.	162.	222.
Non-carbonate hardness (as $CaCO_3$)	124.	—1.6	384.
Hydrogen sulphide	......	......	.15

Hypothetical combinations

Sodium nitrate	......	4.3	......
Sodium chloride	305.3	46.2	198.
Sodium sulphate	133.6	55.3	297.6
Sodium carbonate	......	1.7	......
Magnesium sulphate	148.8	......	168.
Magnesium carbonate	53.8	60.5	......
Calcium sulphate	......	......	331.8
Calcium carbonate	198.	88.4	222.
Iron carbonate	.8	1.7	4.1
Undetermined	32.7	24.9	67.5
Total	873.	283.	1289.

Hypothetical combinations

Sodium nitrate	......	.25	......
Sodium chloride	17.81	2.69	11.55
Sodium sulphate	7.79	3.22	17.35
Sodium carbonate	......	.10	......
Magnesium sulphate	8.68	......	9.80
Magnesium carbonate	3.14	3.53	......
Calcium sulphate	......	......	19.36
Calcium carbonate	11.55	5.15	12.95
Iron carbonate	.05	.10	.24
Undetermined	1.91	1.45	3.94
Total	50.93	16.49	75.19

waters in northeastern Illinois—Continued

Cook	Cook	Cook	Cook	Cook
Chicago	Chicago	Chicago	Chicago	Chicago
(Canalport Ave. & 18th St.)	(Arthington & Homan Ave.)	(Arthington & Homan Ave.)	(27th St. & Cottage Grove Ave.)	(4651 Malcolm Ave.)
Schoenhoffen Brewery	Sears, Roebuck & Co.	Sears, Roebuck & Co.	Seipps Brewery	Sellers Mfg. Co.
2187	1623	1868	1600±	961
75	92	853	To bed rock	To bed rock
150	340	530	200	12
Dec. 17, 1913	June 22, 1914	June 22, 1914	Jan. 13, 1914	Aug. 26, 1914

(parts per million)

136.	128.	160.	184.	8.
.0	.0	.4	.4	4.
.24	.16	.04	.00	.00
1.10	.70	.20	.00	.00
620.	280.	580.	160.	38.
578.3	281.4	273.6	625.	Trace
2135.	1131.	1659.	1384.	238.
240.	230.	230.	212.	119.
556.	236.	352.	440.	—116.
.15	......	......	.17	......

(parts per million)

1.5	1.	.3	......	......
1023.1	462.1	887.8	264.	62.7
492.8	81.8	......	300.3	......
......	......	......	......	123.
163.2	153.6	111.9	220.8	......
......	......	......	......	6.7
163.2	146.9	261.1	348.2	......
240.	230.	230.	212.	25.
......	.8	.8	.8	8.3
51.2	54.8	111.	37.9	12.3
2135.	1131.	1659.	1384.	238.

(parts per U. S. gallon)

.09	.06	.02	......	......
59.68	26.95	51.78	15.40	3.66
28.74	4.76	......	17.50	......
......	......	......	......	7.17
9.51	8.95	6.52	12.87	......
......	......	......	......	.39
9.51	8.56	15.22	20.30	......
14.00	13.42	13.41	12.37	1.46
......	.04	.05	.04	.48
2.98	3.18	6.47	2.21	.72
124.51	65.92	96.74	80.69	13.88

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (1470 Larrabee St.)	Chicago (37th & S. Halsted Sts.)	Chicago (908 W. North Ave.)
Owner	Siebens Brewery	South Side Brewery	Spielman Vinegar Works
Depth of well ... feet	1240	1631	1590
Depth of casing ... feet	98	40	86
Rate of pumping ... gals. per min.	50	75	100
Date sample was collected	Jan. 7, 1914	Dec. 18, 1913	Jan. 6, 1914

Determinations made

Magnesium (as $CaCO_3$)	76.	164.	116.
Iron	.0	.0	1.4
Nitrate nitrogen	.00	.00	.00
Nitrate	.00	.00	.00
Chlorine	62.	250.	76.
Sulphate	135.6	465.8	539.
Residue	560.	1368.	1148.
Alkalinity (as $CaCO_3$)	224.	216.	220.
Non-carbonate hardness (as $CaCO_3$)	—100.	320.	404.
Hydrogen sulphide	......	......	......

Hypothetical combinations

Sodium nitrate	......	......	......
Sodium chloride	102.3	412.6	125.4
Sodium sulphate	200.7	235.	224.9
Sodium carbonate	106.	......	......
Magnesium sulphate	......	196.8	139.2
Magnesium carbonate	63.8	......	......
Calcium sulphate	......	212.7	391.7
Calcium carbonate	48.	216.	220.
Iron carbonate	......	......	2.9
Undetermined	39.2	94.9	43.9
Total	560.	1368.	1148.

Hypothetical combinations

Sodium nitrate	......	......	......
Sodium chloride	5.96	24.06	7.31
Sodium sulphate	11.70	13.71	13.11
Sodium carbonate	6.18	......	......
Magnesium sulphate	......	11.48	8.12
Magnesium carbonate	3.72	......	......
Calcium sulphate	......	12.40	22.85
Calcium carbonate	2.80	12.60	12.83
Iron carbonate	......	......	.17
Undetermined	2.29	5.53	2.56
Total	32.65	79.78	66.95

waters in northeastern Illinois—Continued

Cook Chicago (1225 S. Campbell St.) Standard Brewery	Cook Chicago (15th St. & Ashland Ave.) Steges Brewery	Cook Chicago (42nd St. & Ashland Ave.) Sulzberger Sons & Co.	Cook Chicago (Union Stock Yards) Swift & Co. Bone house	Cook Chicago (Union Stock Yards) Swift & Co. Fertilizer house
2120	1750	1690	1979	2019
70	90	64	72	72
40	45	600	300	250
Jan. 10, 1914	July 18, 1914	July 6, 1914	Sept. 8, 1914	Sept. 9, 1914

(parts per million)

68.	152.	200.	152.	204.
3.6	1.1	.2	.3	.6
.60	.32	.80	.44	.48
2.70	1.4	3.5	1.94	212.2
30.	94.	130.	720.	1500.
53.	472.4	387.6	300.4	201.8
317.	1090.	1037.	1908.	3244.
162.	234.	236.	234.	208.
—44.	306.	256.	352.	598.
......	.26	.26	......	......

(parts per million)

3.7	1.9	4.8	2.7	2.9
49.5	155.1	214.5	1111.5	2005.9
78.4	265.3	210.6	......	......
46.6	......	......	......	......
......	182.4	240.	182.4	244.8
57.1	......	......	41.4	444.8
......	209.4	76.2	219.6	9.2
50.	234.	236.	234.	208.
7.5	2.3	.4	.6	1.2
23.3	39.6	54.5	115.8	327.2
316.1	1090.	1037.	1908.	3244.

(parts per U. S. gallon)

.22	.11	.28	.16	.17
2.88	9.05	12.51	64.81	117.
4.57	15.47	12.28	......	......
2.71	......	......	......	......
......	10.64	14.00	10.64	14.28
3.33	......	......	2.41	25.94
......	12.21	4.44	12.81	.54
2.92	13.65	13.77	13.65	12.13
.44	.13	.02	.03	.07
1.36	2.31	3.18	6.75	19.08
18.43	63.57	60.48	111.26	189.21

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (Union Stock Yards)	Chicago (Union Stock Yards)	Chicago (Union Stock Yards)
Owner	Swift & Co. Hog house	Swift & Co. House No. 5	Swift & Co. Refrigerating Plant
Depth of well feet	2008	1643	2000
Depth of casing feet	70	70±	56
Rate of pumping gals. per min	250	250	300
Date sample was collected	Sept 8, 1914	Sept. 8, 1914	Sept. 8, 1914

Determinations made

Magnesium (as $CaCO_3$)	156.	176.	176.
Iron	.8	.3	.6
Nitrate nitrogen	.52	.84	.32
Nitrate	2.29	3.71	2.21
Chlorine	510.	360.	690.
Sulphate	377.7	355.1	453.
Residue	1625.	1362.	2127.
Alkalinity (as $CaCO_3$)	229.	232.	217.
Non-carbonate hardness (as $CaCO_3$)	302.	332.	176.
Hydrogen sulphide	......	......	......

Hypothetical combinations

Sodium nitrate	3.1	5.2	3.3
Sodium chloride	841.6	594.1	1094.4
Sodium sulphate	130.3	54.6	......
Sodium carbonate	......	......	......
Magnesium sulphate	187.2	211.2	211.2
Magnesium carbonate	......	......	41.9
Calcium sulphate	198.6	212.2	402.6
Calcium carbonate	229.	232.	217.
Iron carbonate	1.7	.6	1.2
Undetermined	33.5	52.1	155.4
Total	1625.	1362.	2127.

Hypothetical combinations

Sodium nitrate	.18	.30	.19
Sodium chloride	49.09	34.65	63.84
Sodium sulphate	7.60	3.18	......
Sodium carbonate	......	......	......
Magnesium sulphate	10.92	12.32	12.32
Magnesium carbonate	......	......	2.44
Calcium sulphate	11.58	12.38	23.54
Calcium carbonate	13.36	13.53	12.66
Iron carbonate	.10	.03	.07
Undetermined	1.95	3.04	9.06
Total	94.78	79.43	124.12

waters of northeastern Illinois—Continued

Cook Chicago (Union Stock Yards) Swift & Co. Oleo. house	Cook Chicago (40th St. & Butler Ave.) Tosetti Brewery	Cook Chicago (16th & Dearborn Sts.) Union Cold Storage Co.)	Cook Chicago (Union Stock Yards) Yards & Transit Co.	Cook Chicago (Union Stock Yards) Union Stock Yards & Transit Co.
			West well	East well
1643±	1366	1135	2180±	2180±
60±	42	90	To bed rock	To bed rock
200	60	20	150	100
Sept. 8, 1914	Dec. 18, 1913	July 15, 1914	July 25, 1914	July 25, 1914

(parts per million)

144.	144.	248.	164.	180.
.4	.8	6.	.1	.2
.20	.24	2.40	.12	.36
.88	1.1	10.60	.5	1.6
460.	250.	55.	1250.	1700.
452.6	553.7	63.8	233.3	141.9
1625.	1456.	......	2441.	3217.
221.	212.	565.	219.	195.
378.	362.	14.	328.	482.
......	......	......	.54	.40

(parts per million)

1.2	1.5	14.5	.7	2.2
759.	412.6	90.8	1956.4	2416.7
134.1	305.9	74.6	......	......
......	......	......	86.8	168.2
172.8	172.8	16.8	86.	......
......	......	......	......	171.5
318.2	296.5	......	223.	201.1
221.	212.	284.3	......	195.
.8	1.6	12.4	.2	.4
17.9	53.1	......	87.9	61.9
1625.	1456.	711.2	2441.	3217.

(parts per U. S. gallon)

.07	.09	.85	.04	.13
44.21	24.06	5.30	114.11	140.97
7.82	17.84	4.35	......	......
......	......	......	5.07	9.81
10.08	10.08	.98	5.02	......
......	......	......	......	11.73
18.56	17.29	......	13.01	10.00
12.89	12.36	16.58	......	11.37
.05	.09	.72	.01	.02
1.04	3.09	......	5.13	3.61
94.72	84.90	41.48	142.39	187.64

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago (Union Stock Yards)	Chicago (20 E. Austin)	Chicago (W. 48th Ave. & 22nd St.)
Owner	Union Yards & Transit Co.	Western Cold Storage Co.	Western Electric Co.
Depth of well, feet	975	2008	1489
Depth of casing, feet	500±	643	68
Rate of pumping, gals. per min.	Drilling	18	500
Date sample was collected	Sept. 26, 1914	July 15, 1914	Aug. 14, 1914

Determinations made

Magnesium (as $CaCO_3$)	124.	92.	128.
Iron	.1	2.8	.2
Nitrate nitrogen	.2	.56	.36
Nitrate	.9	2.5	1.60
Chlorine	245.	330.	190.
Sulphate	171.5	886.7	244.4
Residue	1004.	2068.	924.
Alkalinity (as $CaCO_3$)	360.	225.	257.
Non-carbonate hardness (as $CaCO_3$)	—206.	120.	176.
Hydrogen sulphide	......	......	.08

Hypothetical combinations

Sodium nitrate	1.2	3.4	2.2
Sodium chloride	404.	544.6	313.5
Sodium sulphate	253.8	1142.2	44.1
Sodium carbonate	218.4	......	......
Magnesium sulphate	......	104.7	211.2
Magnesium carbonate	104.1	......	......
Calcium sulphate	......	38.	65.3
Calcium carbonate	30.	220.	257.
Iron carbonate	.2	5.7	.4
Undetermined	43.3	9.4	30.3
Total	1055.	2068.	924.

Hypothetical combinations

Sodium nitrate	.07	.2	.13
Sodium chloride	23.56	31.75	18.28
Sodium sulphate	14.80	66.62	2.57
Sodium carbonate	12.73	......	......
Magnesium sulphate	......	6.11	12.31
Magnesium carbonate	6.07	......	......
Calcium sulphate	......	2.22	3.81
Calcium carbonate	1.75	12.83	14.99
Iron carbonate	.01	.33	.02
Undetermined	2.53	.55	1.77
Total	61.52	120.61	53.88

waters in northeastern Illinois—Continued

Cook Chicago (916 N. Paulina Ave.) West Side Brewery	Cook Chicago (38th St. & Racine Ave.) White Eagle Brewery	Cook Chicago (106th St. & Torrence Ave.) Wisconsin Steel Co.	Cook Chicago (915 S. 5th Ave.) Wrisley Soap Works	Cook Chicago Heights (City Water Works City Well No. 2
2100	1816	1706	1490	300
To bed rock	58	67	75±	50
180	200	150	200	1500
Jan. 8, 1914	Dec. 7, 1913	Aug. 7, 1914	Jan. 12, 1914	July 28, 1914

(parts per million)

128.	136.	220.	156.	240.
.8	.4	1.	.4	.2
.48	.24	.32	.00	.24
.00	1.10	1.41	.00	1.06
780.	140.	255.	98.	8.
679.7	517.6	809.3	458.	191.9
2544.	1222.	1839.	1027.	628.
216.	212.	221.	202.	376.
296.	362.	530.	312.	162.
......	......	.39	......	......

(parts per million)

2.1	1.5	1.9	......	1 5
1287.1	231.	420.8	161.7	13 2
584.7	252.2	445.4	235.2	54 6
......	......	......	......	......
153.6	163.2	264.	187.2	194.4
......	......	......	......	65.5
228.9	307.4	421.6	212.2	......
216.	212.	......	202.	298.
1.7	.8	221.	.8	.4
69.9	53.9	62.2	27.9	.4
2544.	1222.	1839.	1027.	628.

(parts per U. S. gallon)

.12	.09	.11	......	.09
75.05	13.47	24.54	9.43	.77
34.20	14.70	25.98	13.72	3.18
......	......	......	......	......
8.95	9.52	15.40	10.92	11.33
......	......	......	......	3.82
13.34	17.92	24.59	12.37	......
12.60	12.37	12.89	11.78	17.38
.10	.05	.12	.05	.02
4.07	3.14	3.62	1.63	.02
148.43	71.26	107.25	59.90	36.61

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Chicago Heights (City Water Works)	South Chicago Heights	Clearing SW. ¼ Sec. 21, T. 38 N., R. 13 E.
Owner	City	Village	C. & W. I. R. R.
	Well No. 3		Well No. 1
Depth of well, feet	300	2700±	1554
Depth of casing, feet	50±	65	84
Rate of pumping, gals. per min.	1500	150	250
Date sample was collected	July 28, 1914	July 28, 1914	July 9, 1914

Determinations made

Magnesium (as $CaCO_3$)	288.	192.	124.
Iron	.4	.0	.7
Nitrate nitrogen	.48	.40	.08
Nitrate	2.10	1.80	.35
Chlorine	11.	11.	45.
Sulphate	319.7	20.2	164.6
Residue	817.	451.	480.
Alkalinity (as $CaCO_3$)	372.	414.	148.
Non-carbonate hardness (as $CaCO_3$)	300.	8.	82.

Hypothetical combinations

Sodium nitrate	2.9	2.5	.5
Sodium chloride	18.2	18.2	74.3
Sodium sulphate	47.9	29.9	127.5
Sodium carbonate	......	8.5	......
Magnesium sulphate	345.6	......	98.4
Magnesium carbonate	......	161.3	35.3
Calcium sulphate	16.3	......	......
Calcium carbonate	372.	213.5	106.
Iron carbonate	.8	......	1.5
Undetermined	13.3	17.1	36.5
Total	817.	451.	480.

Hypothetical combinations

Sodium nitrate	.17	.15	.03
Sodium chloride	1.06	1.06	4.33
Sodium sulphate	2.79	1.74	7.44
Sodium carbonate	......	.5	......
Magnesium sulphate	20.16	......	5.74
Magnesium carbonate	......	9.40	2.06
Calcium sulphate	.95	......	......
Calcium carbonate	21.70	12.45	6.18
Iron carbonate	.05	......	.09
Undetermined	.78	1.00	2.13
Total	47.66	26.30	28.00

waters in northeastern Illinois—Continued

Cook	Cook	Cook	Cook	Cook
Clearing	Clearing	Des Plaines	Harvey	Harvey
SW. ¼, Sec. 21, T. 38, N., R. 13 E.	SW. ¼, Sec. 21, T. 38 N., R. 13 E.	(City Water-works)	(155th St. near I. C. R. R.)	(City Water Works)
C. & W. I. R. R.	C. & W. I. R. R.	City	Austin Mfg. Co.	Public Service Co. of N. Ill.
Well No. 2	Well No. 3			Well No. 1
1586	1584	125	1128	1320±
80	100	125	20±	To bed rock
225	225	45	30±	85±
July 9, 1914	July 9, 1914	Aug. 17, 1914	July 26, 1914	July 27, 1914

(parts per million)

156.	160.	232.	180.	136.
.2	.6	.8	.3	3.
.80	.80	.88	.40	6.00
3.50	3.50	3.88	1.80	26.50
18.	37.	330.	220.	47.
282.6	228.8	200.4	662.5	94.6
589.	582.	1070.	1564.	574.
127.	163.	170.	225.	332.
182.	128.	298.	434.	—37.2

(parts per million)

4.8	4.8	5.3	2.5	36.3
29.7	61.1	440.8	363.	77.6
167.4	157.3	......	492.8	140.
......	......	......	......	39.5
187.2	153.6	251.1	216.	......
......	26.9	($MgCl_2$) 21.5	......	114.2
35.8	......	($CaCl_2$) 73.7	227.4	......
127.	131.	170.	225.±	158.7
.4	1.2	.8	.6	6.2
36.7	46.1	106.8	37.7	1.5
589.	582.	1070.	1565.	574.

(parts per U. S. gallon)

.28	.28	.31	.15	2.12
1.73	3.56	25.70	21.17	4.52
9.76	9.17	......	28.74	8.16
......	......	......	......	2.30
10.92	8.96	14.64	12.60	......
......	1.57	($MgCl_2$) 1.25	......	6.66
2.09	......	($CaCl_2$) 4.28	13.26	......
7.41	7.64	9.92	13.12	9.25
.02	.07	.05	.03	.36
2.14	2.69	6.23	2.20	.09
34.35	33.94	62.38	91.27	33.46

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Harvey (City Water-works)	Harvey (City Water-works)	Hubbard Woods ......
Owner	Public Service Co. of N. Ill. Well No. 2	Public Service Co. of N. Ill. Well No. 4	North Shore Ice Co.
Depth of well ... feet	1600±	1600±	1437
Depth of casing ... feet	To bed rock	To bed rock	180±
Rate of pumping ... gals. per min.	100±	200±	140
Date sample was collected	July 27, 1914	July 26, 1914	Aug. 25, 1914
Determinations made			
Magnesium (as $CaCO_3$)	164.	184.	120.
Iron	.0	.1	.4
Nitrate nitrogen	.28	.80	.00
Nitrate	1.3	3.50	.00
Chlorine	180.	145.	37.
Sulphate	576.	513.	321.
Residue	1366.	1268.	794.
Alkalinity (as $CaCO_3$)	216.	270.	236.
Non-carbonate hardness (as $CaCO_3$)	366.	338.	190.
Hypothetical combinations			
Sodium nitrate	1.8	5.	......
Sodium chloride	297.	239.3	61.1
Sodium sulphate	332.9	279.7	205.4
Sodium carbonate	......	......	......
Magnesium sulphate	196.8	220.8	144.
Magnesium carbonate	......	......	......
Calcium sulphate	274.7	209.4	95.2
Calcium carbonate	216.	270.	236.
Iron carbonate	......	.2	.8
Undetermined	46.8	43.6	51.5
Total	1366.	1268.	794.
Hypothetical combinations			
Sodium nitrate	.11	.29	......
Sodium chloride	17.32	13.96	3.56
Sodium sulphate	19.42	16.21	11.98
Sodium carbonate	......	......	......
Magnesium sulphate	11.48	12.88	8.40
Magnesium carbonate	......	......	......
Calcium sulphate	16.02	12.21	5.55
Calcium carbonate	12.60	15.75	13.77
Iron carbonate	......	.01	.05
Undetermined	2.73	2.54	3.00
Total	79.68	73.95	46.31

waters in northeastern Illinois—Continued

Cook	Cook	Cook	Cook	Cook
La Grange (City Water Works)	La Grange (City Water Works)	Lemont (City Water Works)	Lyons (City Water Works)	Maywood (St. Charles Road & 9th Ave.)
Public Service Co. of N. Ill. Well No. 1	Public Service Co. of N. Ill. Well No. 2	Public Service Co. of N. Ill.	City	American Can Co.
1990	2000±	2284	1595	1607
10±	10±	To bed rock	To bed rock	55±
400	400	125	50	150±
June 19, 1914	June 19, 1914	Sept. 24, 1915	July 29, 1914	Aug. 6, 1914

(parts per million)

160.	184.	80.	176.	220.
.4	.8	.6	.1	.3
.60	.80	......	2.20	.52
2.7	3.50	.33	9.70	2.29
36.	15.	590.	21.	6.
118.9	160.1	46.	146.9	223.
572.	524.	1332.	511.	540.
348.	236.	300.	250.	230.
92.	132.	—40.	134.	138.

(parts per million)

3.7	4.8	......	12.7	3.1
59.4	24.8	974.	34.6	9.9
45.7	49.5	68.	27.9	133.3
......	......	42.	......	......
110.4	158.4	......	160.8	165.6
57.1	43.7	.67	35.3	68.9
......	......	......	......	......
280.	184.	180.	208.	148.
.8	.8	1.	.2	.6
14.9	58.	......	31.5	10.6
572.	524.	1332.	511.	540.

(parts per U. S. gallon)

.22	.28	......	.74	.18
3.46	1.43	56.81	2.02	.58
2.66	2.88	3.97	1.63	7.77
......	......	2.45	......	......
6.43	9.23	......	9.38	9.66
3.33	2.54	3.91	2.06	4.01
......	......	......	......	......
16.33	10.73	10.50	12.13	8.63
.05	.04	.06	.01	.03
.87	3.38	......	1.84	.62
33.35	30.51	77.70	29.81	31.48

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Maywood	Melrose Park	Melrose Park
Owner	(City Water-works) City	(City Water-works) City Well No. 1	(City Water-works) City Well No. 2
Depth of well.....feet	1605	1620	1571
Depth of casing.....feet	53	To bed rock	94
Rate of pumping.....gals. per min.	725	420	520
Date sample was collected	Aug. 6, 1914	Aug. 12, 1914	Aug. 12, 1914

Determinations made

Magnesium (as $CaCO_3$)	180.	172.	140.
Iron	.8	.4	.1
Nitrate nitrogen	.24	.32	.56
Nitrate	1.06	1.41	2.48
Chlorine	42.	7.	6.
Sulphate	226.3	194.1	195.
Residue	592.	566.	547.
Alkalinity (as $CaCO_3$)	216.	277.	271.
Non-carbonate hardness (as $CaCO_3$)	152.	116.	114.
Hydrogen sulphide	.22	......	......

Hypothetical combinations

Sodium nitrate	1.5	1.9	3.4
Sodium chloride	69.3	11.6	9.9
Sodium sulphate	119.4	122.6	128.4
Sodium carbonate	......	......	......
Magnesium sulphate	182.4	139.2	136.8
Magnesium carbonate	23.7	47.	21.8
Calcium sulphate	......	......	......
Calcium carbonate	188.	221.	245.
Iron carbonate	1.7	.8	.2
Undetermined	6.	21.9	1.5
Total	592.	566.	547.

Hypothetical combinations

Sodium nitrate	.08	.11	.20
Sodium chloride	4.04	.68	.58
Sodium sulphate	6.96	7.15	7.48
Sodium carbonate	......	......	......
Magnesium sulphate	10.64	8.11	7.98
Magnesium carbonate	1.38	2.74	1.27
Calcium sulphate	......	......	......
Calcium carbonate	10.96	12.89	14.29
Iron carbonate	.10	.05	.01
Undetermined	.35	1.28	.09
Total	34.51	33.01	31.90

waters in northeastern Illinois—Continued

Cook	Cook	Cook	Cook	Cook
Park Ridge	Park Ridge	Proviso Township	Proviso Township	Proviso Township
(City Water Works) City	(City Water Works) City	(SE. ¼ NW. ¼ sec. 5 C. & N. W. R. R. Well No. 1	(SE. ¼ NW. ¼ sec. 5 C. & N. W. R. R. Well No. 2	(SE. ¼ NW. ¼ sec. 5) C. & N. W. R. R. Well No. 5
1804	1425	1825	1200	1841
100±	100±	1551	66	1723
175	175	107	150	105
Aug. 26, 1914	Aug. 26, 1914	March 3, 1914	June 30, 1915	Mar. 3, 1914

(parts per million)

76.	112.	0.	152.	0.
.4	8.	.4	.2	.0
.40	.64	.80	......	.64
1.77	4.42	3.5	2.1	2.8
105.	155.	22.	23.	42.
355.9	260.9	98.3	144.4	41.6
919.	885.	486.	520.	426.
213.	195.	268.	270.	268.
48.	84.	—52.	46.	—156.
......	......	......	......	......

(parts per million)

2.4	6.6	4.8	2.9	3.8
173.3	255.8	36.3	38.	69.3
458.6	269.3	145.4	148.6	61.5
......	......	55.1	......	165.4
57.6	105.6	......	55.2	......
23.5	20.2	......	89.	......
......	......	......	......	......
185.	171.	216.	164.	112.
.8	16.6	......	.4	......
17.8	39.9	28.4	21.9	14.
919.	885.	486.	520.	426.

(parts per U. S. gallon)

.14	.38	.28	.17	.22
10.11	14.92	2.12	2.22	4.04
26.75	15.71	8.47	8.67	3.60
......	......	3.21	......	9.64
3.36	6.16	......	3.22	......
1.37	1.18	......	5.19	......
......	......	......	......	......
10.79	9.97	12.60	9.57	6.53
.05	.97	......	.02	......
1.04	2.33	1.66	1.28	.81
53.61	51.62	28.34	30.34	24.84

TABLE II.—*Boiler analyses of underground*

County	Cook	Cook	Cook
Town	Proviso Township (SE. ¼ NW. ¼ sec. 5)	Proviso Township (SE. ¼ NW. ¼ sec. 5)	Riverdale (City Waterworks)
Owner	C. & N. W. R. R. Well No. 9	C. & N. W. R. R. Well No. 11	City
Depth of well ... feet	1849	1850	434
Depth of casing ... feet	1522	1679	58
Rate of pumping ... gals. per min.	93	100	160
Date sample was collected	Mar. 3, 1914	Mar. 3, 1914	July 23, 1914

Determinations made

Magnesium (as $CaCO_3$)	0.	0.	60.
Iron	.0	.1	.5
Nitrate nitrogen	.16	1.44	.48
Nitrate	.70	6.20	2.10
Chlorine	46.	26.	17.
Sulphate	44.8	37.2	96.3
Residue	454.	370.	433.
Alkalinity (as $CaCO_3$)	288.	244.	245.
Non-carbonate hardness (as $CaCO_3$)	—164.	—140.	—142.
Hydrogen sulphide	......	......	......

Hypothetical combinations

Sodium nitrate	1.	8.5	2.9
Sodium chloride	75.9	42.9	28.
Sodium sulphate	66.3	55.	142.5
Sodium carbonate	173.8	148.4	150.5
Magnesium sulphate	......	......	......
Magnesium carbonate	......	......	50.4
Calcium sulphate	......	......	......
Calcium carbonate	124.	104.	43.
Iron carbonate	......	......	1.
Undetermined	13.	11.2	14.7
Total	454.	370.	433.

Hypothetical combinations

Sodium nitrate	.01	.49	.17
Sodium chloride	4.42	2.49	1.63
Sodium sulphate	3.86	3.20	8.31
Sodium carbonate	10.14	8.65	8.78
Magnesium sulphate	......	......	......
Magnesium carbonate	......	......	2.94
Calcium sulphate	......	......	......
Calcium carbonate	7.23	6.07	2.51
Iron carbonate	......	......	.06
Undetermined	.76	.65	.86
Total	26.42	21.55	25.26

waters in northeastern Illinois—Continued

Cook	Cook	Cook	Cook	Cook
River Forest	River Forest	Riverside	Summit	Summit
(City Water Works)	(City Water Works)	(City Water Works)	(City Water Works)	(City water-works)
City	City	City	City	City
Well No. 1	Well No. 2	West Well		
1000±	980	1980	1547	......
54	54	302	60±	58
109	150	240	175	......
Aug. 15, 1914	Aug. 15, 1914	July 29, 1914	July 20, 1914	Aug. 21, 1914

(parts per million)

108.	84.	168.	156.	128.
.2	.1	.3	.1	.2
.32	.40	.32	.32	1.00
1.41	1.8	1.4	1.4	4.42
9.	8.	65.	100.	14.
189.6	128.3	167.9	139.9	81.9
526.	437.	670.	672.	423.
245.	229.	342.	288.	262.
42.	—26.	—4.	—24.	12.
.70	1.86	......	.19	......

(parts per million)

1.9	2.5	1.9	1.9	6.1
14.9	13.2	105.6	165.	23.1
221.	189.9	248.5	207.	104.2
......	27.6	1.2	25.4	......
50.4	......	......	......	14.4
55.4	70.6	141.1	131.	97.4
......	......	......	......	......
179.	119.	170.	108.	146.
.4	.2	.6	.2	.4
3.	14.	1.1	33.5	31.4
526.	437.	670.	672.	423.

(parts per U. S. gallon)

.11	.16	.11	.11	.36
.87	.77	6.16	9.62	1.35
12.89	11.07	14.49	12.07	6.08
......	1.61	.07	1.48	......
2.93	......	......	......	.84
3.22	4.12	8.23	7.64	5.68
......	......	......	......	......
10.44	6.94	9.92	6.30	8.52
.02	.01	.03	.01	.02
.17	.82	.06	1.95	1.83
30.65	25.50	39.07	39.18	24.68

TABLE II.—*Boiler analyses of underground*

County	De Kalb	Du Page	Du Page
Town	Sycamore	Bensenville	Downers Grove
	(Waterworks)	(Near Station)	(Waterworks)
Owner	De Kalb & Sycamore Electric R. R. Well No. 1	C. M. & St. P. R. R.	City
Depth of well.....feet	902	2290	250
Depth of casing.....feet	170	1236	To bed rock
Rate of pumping.....gals. per min.	150	170	75
Date sample was collected	July 15, 1915	Mar. 4, 1914	Aug. 4, 1914

Determinations made

Magnesium (as $CaCO_3$)	160	0.	220.
Iron	.1	.1	.2
Nitrate nitrogen	......	.32	.28
Nitrate	1.1	1.4	1.24
Chlorine	9.9	46.	6.
Sulphate	361.	45.7	125.9
Residue	345.	430.	444.
Alkalinity (as $CaCO_3$)	—24.	268.	244.
Non-carbonate hardness (as $CaCO_3$)	......	—160.	110.

Hypothetical combinations

Sodium nitrate	1.5	1.9	1.7
Sodium chloride	1.7	75.9	9.9
Sodium sulphate	14.7	67.6	30.5
Sodium carbonate	25.4	169.6	......
Magnesium sulphate	......	......	132.
Magnesium carbonate	134.4	......	92.4
Calcium sulphate	......	......	......
Calcium carbonate	161.	108.	134.
Iron carbonate	.2	......	.4
Undetermined	22.1	7.	43.1
Total	361.	430.	444.

Hypothetical combinations

Sodium nitrate	.09	.11	.01
Sodium chloride	.10	4.42	.58
Sodium sulphate	.86	3.93	1.78
Sodium carbonate	1.48	9.88	......
Magnesium sulphate	......	......	7.70
Magnesium carbonate	7.84	......	5.38
Calcium sulphate	......	......	......
Calcium carbonate	9.39	6.30	7.82
Iron carbonate	.01	......	.02
Undetermined	1.29	.40	2.51
Total	21.06	25.04	25.80

waters in northeastern Illinois—Continued

Du Page Elmhurst	Du Page Elmhurst	Du Page Elmhurst	Du Page Hinsdale	Du Page Lombard
(Waterworks) City Well No. 1	(Waterworks) City	(Waterworks) City	(Waterworks) City	(Waterworks) Village
301	958	958	268	89
76	76	76	To bed rock	......
152	325	410	500±	330
July 9, 1915	Sept. 2, 1915	Sept. 20, 1915	Aug. 5, 1914	Aug. 12, 1914

(parts per million)

232.	156.	164.	148.	148.
......	.2	.3	.5	1.5
......	.56	.44	.0	.48
......	2.47	1.94	.0	2.12
6.	5.	5.	0.	4.
0.	56.	53.	174.5	44.8
465.	413.	408.	534.	405.
375.	322.	315.	270.	350.
—8.	20.	20.	116.	10.

(parts per million)

......	3.	3.	......	2.9
10.	8.	8.	......	6.6
117.	55.	50.	94.	49.1
8.	......	......	......	......
......	24.	24.	139.2	12.
195.	114.	121.	26.9	117.9
......	......	......	......	......
135.	186.	171.	238.	212.
......	......	......	......	3.1
......	23.	31.	35.9	1.4
465.	413.	408.	534.	405.

(parts per U. S. gallon)

......	.17	.17	......	.17
.58	.47	.47	......	.38
6.82	3.21	2.92	5.48	2.86
.47	......	......	......	......
......	1.40	1.40	8.11	.70
11.37	6.65	7.06	1.57	6.87
......	......	......	......	......
7.87	10.85	9.97	13.88	12.37
......	......	......	......	.18
......	1.34	1.81	2.08	.08
27.11	24.09	23.80	31.12	23.61

TABLE II.—*Boiler analyses of underground*

County	Du Page	Du Page	Du Page
Town	Naperville (SW. ¼ sec. 18, T. 38 N., R. 10 E.)	West Chicago (Waterworks)	West Chicago (Waterworks)
Owner	Mr. Goodwin	City New Well	City Old Well
Depth of well, feet	Spring	322	715
Depth of casing, feet	......	90	90
Rate of pumping, gals. per min.	Flows 10±	100±	100±
Date sample was collected	July 13, 1915	Aug. 13, 1914	Aug. 13, 1914
Determinations made			
Magnesium (as $CaCO_3$)	232.	148.	148.
Iron	0.	.4	1.2
Nitrate nitrogen	......	.32	.36
Nitrate	44.2	2.29	1.6
Chlorine	22.	23.	11.
Sulphate	111.5	106.	50.2
Residue	605.	485.	366.
Alkalinity (as $CaCO_3$)	330.	300.	275.
Non-carbonate hardness (as $CaCO_3$)	84.	80.	10.
Hypothetical combinations			
Sodium nitrate	60.6	3.1	2.2
Sodium chloride	36.3	37.9	18.2
Sodium sulphate	46.	43.5	60.
Sodium carbonate	......	......	......
Magnesium sulphate	100.8	96.	12.
Magnesium carbonate	124.3	57.1	117.9
Calcium sulphate	......	......	......
Calcium carbonate	182.	232.	137.
Iron carbonate	......	.8	2.5
Undetermined	55.	14.6	16.2
Total	605.	485.	366.
Hypothetical combinations			
Sodium nitrate	3.53	.18	.13
Sodium chloride	2.12	2.21	1.06
Sodium sulphate	2.68	2.53	3.50
Sodium carbonate	......	......	......
Magnesium sulphate	5.88	5.60	.70
Magnesium carbonate	7.25	3.33	6.87
Calcium sulphate	......	......	......
Calcium carbonate	10.62	13.53	7.99
Iron carbonate	......	.05	.15
Undetermined	3.21	.85	.94
Total	35.29	28.28	21.34

waters in northeastern Illinois—Continued

Du Page West Chicago (Roundhouse)	Du Page West Chicago (Roundhouse)	Du Page Wheaton (Waterworks)	Grundy Carbon Hill (Waterworks)	Grundy Coal City (Waterworks)
C. & N. W. R. R.	C. & N. W. R. R.	City	City	City
2081	(Dug) 30	175	1900	350
......	......	110	150±	100
100±	300±	335	15±	180
Aug. 13, 1914	Aug. 13, 1914	Aug. 13, 1914	Sept. 29, 1915	Sept. 29, 1915

(parts per million)

120.	192.	88.	168.	160.
.4	.1	.5	.4	.3
1.2	5.	.48	......	......
5.3	22.1	2.12	1.77	1.94
3.	26.	1.	290.	260.
41.6	134.	48.6	382.	350.
363.	588.	356.	1296.	1190.
300.	325.	270.	252.	252.
12.	134.	0.	188.	136.

(parts per million)

7.3	30.3	2.9	2.	3.
5.	42.9	1.7	479.	429.
44.4	8.4	71.9	299.	326.
......	......	......	......	......
14.4	160.8	......	202.	163.
90.7	48.7	73.9	......	20.
......	....	......	27.	......
192.	267.	182.	252.	228.
.8	.2	1.	1.	1.
8.4	29.7	22.6	34.	20.
363.	588.	356.	1296.	1190.

(parts per U. S. gallon)

.43	1.77	.17	.12	.17
.29	2.49	.10	27.94	25.02
2.58	.49	4.18	17.44	19.02
......	......	......	......	......
.84	9.38	......	11.78	9.51
5.28	2.83	4.30	......	1.17
......	......	......	1.57	......
11.20	15.57	10.62	14.70	13.30
.05	.01	.06	.06	.06
.50	1.73	1.32	1.98	1.17
21.17	34.27	20.75	75.59	69.42

TABLE II.—*Boiler analyses of underground*

County	Grundy	Grundy	Kane
Town	Minooka (Waterworks)	Morris (614 W. Washington St.)	Aurora (Pumping Station)
Owner	City	Gebhard Brewery	City Well No. 2
Depth of well.......feet	620	......	2300±
Depth of casing.......feet	100±	......	300±
Rate of pumping.......gals. per min.	50	35	250±
Date sample was collected	Sept. 23, 1915	Sept. 22, 1915	July 2, 1915

Determinations made

Magnesium (as $CaCO_3$)	84.	116.	184.
Iron	.03	.4	.1
Nitrate nitrogen	......	......	......
Nitrate	2.65	1.06	2.1
Chlorine	530.	15.	510.
Sulphate	42.	39.	74.5
Residue	1182.	370.	1248.
Alkalinity (as $CaCO_3$)	270.	300.	248.
Non-carbonate hardness (as $CaCO_3$)	—48.	—36.	184.

Hypothetical combinations

Sodium nitrate	4.	1.	2.9
Sodium chloride	874.	25.	734.2
Sodium sulphate	62.	58.	$MgCl_2$ 90.9
Sodium carbonate	51.	38.	......
Magnesium sulphate	......	......	93.4
Magnesium carbonate	71.	97.	......
Calcium sulphate	......	......	......
Calcium carbonate	138.	163.	248.
Iron carbonate	1.	1.	.2
Undetermined	......	......	78.4
Total	1201.	383.	1248.

Hypothetical combinations

Sodium nitrate	.23	.06	.17
Sodium chloride	50.98	1.46	42.82
Sodium sulphate	3.62	3.38	$MgCl_2$ 5.30
Sodium carbonate	2.97	2.22	......
Magnesium sulphate	......	......	5.45
Magnesium carbonate	4.14	5.66	......
Calcium sulphate	......	......	......
Calcium carbonate	8.05	9.51	14.47
Iron carbonate	.06	.06	.01
Undetermined	......	......	4.57
Total	70.05	22.35	72.79

waters in northeastern Illinois—Continued

Kane	Kane	Kane	Kane	Kane
Aurora	Aurora	Aurora	Aurora	Aurora
(Phillips Park)	(Lake St.)	(River St.)	(River St.)	(Farnsworth St. & R. R. Tracks)
City	Aurora Bleachery	Aurora Brewery	Aurora Brewery	Aurora Wheeled Scraper Co.
2759	1280	250	Spring	1410
320	To bed rock	To bed rock	......	1200
125	400±	60	15	40
July 15, 1915	July 3, 1915	July 4, 1915	July 3, 1915	July 8, 1915

(parts per million)

208.	124.	188.	232.	132.
......	0.	......	0.	.2
......	......	......	......	......
1.06	10.6	8.8	70.7	2.9
1300.	12.	64.	48.	14.
98.	50.2	132.1	156.8	85.6
2992.	378.	655.	694.	428.
264.	280.	365.	282.	278.
632.	—28.	—4.	136.	—18.

(parts per million)

1.	14.5	12.1	97.	4.
1537.	19.8	105.6	79.2	23.1
$MgCl_2$ 196.	74.3	195.5	39.4	126.7
......	29.7	4.2	......	19.1
......	......	......	163.2	......
$CaCl_2$ 354.	104.1	157.9	80.6	110.9
139.	......	......	......	......
264.	128.	173.	186.	128.
......	......	......	......	.4
......	7.6	6.7	48.6	15.8
2491.	378.	655.	694.	428.

(parts per U. S. gallon)

.58	.85	.71	5.66	.23
89.64	1.15	6.16	4.62	1.35
$MgCl_2$ 11.43	4.33	11.40	2.3	7.39
......	1.73	2.4	......	1.11
......	......	......	9.52	......
$CaCl_2$ 20.65	6.07	9.21	4.70	6.47
8.11	......	......	......	......
15.40	7.47	10.09	10.85	7.47
......	......	......	......	.02
......	.44	.39	2.83	.92
145.81	22.04	38.20	40.48	24.96

TABLE II.—*Boiler analyses of underground*

County	Kane	Kane	Kane
Town	Aurora (160 N. Highland Ave.)	Aurora (Farnsworth St. & R. R. Tracks)	Elgin
Owner	W. B. Davis' Greenhouse	Munroe Bindery	Elgin Watch Co.
Depth of well ... feet	69	1420	2000±
Depth of casing ... feet	24	60	To bed rock
Rate of pumping ... gals. per min.	140	225	50
Date sample was collected	July 19, 1915	July 8, 1915	Sept. 30, 1914

Determinations made

Magnesium (as $CaCO_3$)	184.	148.	60.
Iron	......	.2	.2
Nitrate nitrogen	......	......	.3
Nitrate	1.1	2.1	1.3
Chlorine	9.	15.	24.
Sulphate	......	94.6	33.
Residue	344.	450.	318.
Alkalinity (as $CaCO_3$)	347.	278.	202.
Non-carbonate hardness (as $CaCO_3$)	......	—8.	10.

Hypothetical combinations

Sodium nitrate	1.5	2.9	1.8
Sodium chloride	14.9	24.8	39.6
Sodium sulphate	40.8	140.	34.6
Sodium carbonate	12.7	8.5	......
Magnesium sulphate	......	......	12.
Magnesium carbonate	154.6	124.3	42.
Calcium sulphate	......	......	......
Calcium carbonate	151.	122.	152.
Iron carbonate	2.1	.4	.4
Undetermined	......	27.1	35.6
Total	377.6	450.	318.

Hypothetical combinations

Sodium nitrate	.09	.17	.10
Sodium chloride	.87	1.45	2.31
Sodium sulphate	2.38	8.17	2.02
Sodium carbonate	.74	.50	......
Magnesium sulphate	......	......	.70
Magnesium carbonate	9.02	7.25	2.45
Calcium sulphate	......	......	......
Calcium carbonate	8.81	7.12	8.87
Iron carbonate	.12	.02	.02
Undetermined	......	1.58	2.08
Total	22.03	26.26	18.55

waters in northeastern Illinois—Continued

Kane Elgin	Kane Elgin (Waterworks)	Kane Mooseheart (N.E. ¼ sec. 33 T. 39 N., R. 8 E.)	Kane St. Charles (Waterworks)	Kane St. Charles (Park Street)
Elgin Watch Co.	City	Order of Moose	City	City
500	1300	1840	350	850
40	......	39	To bed rock	60±
50	......	100	120	200
Sept. 30, 1914	Aug. 9, 1915	July 10, 1915	Sept. 30, 1914	Sept. 30, 1914

(parts per million)

52.	100.	184.	144.	96.
.3	.1	.1	.0	.1
1.4	(H_2SO_4) .9	......	6.8	.3
6.2	......	1.8	29.2	1.3
25.	8.	7.	27.	5.
30.4	37.	41.1	97.	26.7
426.	371.	397.	537.	369.
320.	304.	340.	280.	326.
—156.	16.	12.	22.	—56.

(parts per million)

8.5	......	2.5	39.8	1.8
41.2	13.	11.6	44.5	8.2
45.	55.	43.8	112.3	39.4
166.	17.	......	......	59.4
......	......	14.4	26.4	......
43.7	84.	144.5	102.5	80.6
......	......	......	......	......
112.	204.	168.	158.	174.
.6	2.	.2	.0	.2
9.	......	12.	53.5	5.4
426.	375.	397.	537.	369.

(parts per U. S. gallon)

.49	......	.15	2.32	.11
2.40	.76	.68	2.60	.48
2.62	3.21	2.55	6.54	2.30
9.68	.99	......	......	3.46
......	......	.84	1.54	......
2.55	4.9	8.43	5.97	4.70
......	......	......	......	......
6.53	11.9	9.80	9.22	10.15
.03	.12	.01	.00	.01
.52	......	.70	3.12	.31
24.82	21.88	23.16	31.31	21.52

TABLE II.—*Boiler analyses of underground*

County	Kankakee	Kankakee	Kankakee
Town	Bradley	Kankakee (396 S. Schuyler St.)	Kankakee (600 S. Dearborn St.)
Owner	Bradley Mfg. Co.	Kankakee Pure Milk Co.	Radeke Brewery
Depth of well . . . feet	244	205	225
Depth of casing . . . feet	200±	30	25±
Rate of pumping . . . gals. per min.	200±	75	80
Date sample was collected	Oct. 1, 1915	Oct. 2, 1915	Sept. 30, 1915

Determinations made

Magnesium (as $CaCO_3$)	140.	180.	200.
Iron	.8	1.	3.
Nitrate nitrogen	......	......	......
Nitrate	3.36	2.12	47.7
Chlorine	16.	25.	30.
Sulphate	57.	186.	175.
Residue	450.	758.	703.
Alkalinity (as $CaCO_3$)	427.	415.	345.
Non-carbonate hardness (as $CaCO_3$)	48.	156.	136.

Hypothetical combinations

Sodium nitrate	5.	3.	65.
Sodium chloride	26.	41.	50.
Sodium sulphate	16.	55.	67.
Sodium carbonate	......	......	......
Magnesium sulphate	58.	187.	163.
Magnesium carbonate	77.	20.	54.
Calcium sulphate	......	......	......
Calcium carbonate	235.	391.	281.
Iron carbonate	2.	2.	1.
Undetermined	31.	59.	22.
Total	450.	758.	703.

Hypothetical combinations

Sodium nitrate	.29	.17	3.79
Sodium chloride	1.52	2.39	2.92
Sodium sulphate	.93	3.21	3.91
Sodium carbonate	......	......	......
Magnesium sulphate	3.38	10.91	9.51
Magnesium carbonate	4.49	1.17	3.15
Calcium sulphate	......	......	......
Calcium carbonate	13.71	22.81	16.39
Iron carbonate	.12	.12	.06
Undetermined	1.81	3.44	1.28
Total	26.25	44.22	41.01

waters in northeastern Illinois—Continued

Kankakee Kankakee	Kankakee Kankakee	Kendall Oswego (Waterworks)	Lake Highland Park (One Mile West at Blodgett)	Lake Highland Park (SE. ¼ sec. 21, T. 43 N., R. 12 E.)
State Hospital Well No. 1	State Hospital Well No. 2	Village	C. & N. W. R. R.	Mr. R. Tillman
1812	1847	(Dug) 22	1760	168
75±	75±	......	121	160±
250±	250±	40	300±	2±
Sept. 30, 1915	Sept. 30, 1915	July 20, 1915	Aug. 20, 1914	Aug. 24, 1914

(parts per million)

268.	188.	172.	36.	172.
.3	.3	.6	.4	.2
......	......	......	.48	.8
1.41	2.65	2.47	2.12	3.5
550.	176.	10.	25.	9.
671.	265.	97.	15.2	276.9
2197.	978.	410.	231.	609.
233.	288.	307.	163.	170.
452.	192.	64.	—44.	738.

(parts per million)

2.	4.	3.	2.9	4.8
908.	290.	17.	41.3	14.9
327.	121.	53.	22.5	214.3
......	......	......	46.6	......
322.	226.	77.	......	165.6
......	......	91.	30.2	28.6
274.	5.	......	......	......
233.	288.	199.	83.	136.
1.	1.	......	.8	.4
130.	43.	......	3.7	44.4
2197.	978.	440.	231.	609.

(parts per U. S. gallon)

.12	.23	.17	.17	.28
52.96	16.92	.99	2.41	.87
19.07	7.06	3.09	1.31	12.50
......	......	.....	2.72	......
18.78	13.18	4.49	......	9.66
......	......	5.31	1.76	1.67
15.98	.29	......	......	......
13.59	16.80	11.61	4.84	7.93
.06	.06	......	.05	.02
7.58	2.51	......	.22	2.59
128.14	57.05	25.66	13.48	35.52

TABLE II.—*Boiler analyses of underground*

County	Lake	Lake	Lake
Town	Lake Bluff (Waterworks)	Lake Bluff (Waterworks)	Lake Forest
Owner	City	City	Ogden Armour
Depth of well .... feet	498	1900±	1600±
Depth of casing .... feet	193	195	150
Rate of pumping .... gals. per min.	55	75	200±
Date sample was collected	Sept. 1, 1914	Sept. 1, 1914	Oct. 7, 1915

Determinations made

Magnesium (as $CaCO_3$)	24.	56.	......
Iron	.2	.1	.5
Nitrate nitrogen	.28	.0	......
Nitrate	.92	0	4 07
Chlorine	16.	16.	12.
Sulphate	105.3	181.9	......
Residue	318.	580.	450.
Alkalinity (as $CaCO_3$)	120.	251.	277.
Non-carbonate hardness (as $CaCO_3$)	—32.	122.	......

Hypothetical combinations

Sodium nitrate	1.3	......	6.
Sodium chloride	26.4	26.4	20.
Sodium sulphate	155.8	95.4	124.
Sodium carbonate	33.9	......	......
Magnesium sulphate	......	67.6	29.
Magnesium carbonate	20.2	......	30.
Calcium sulphate	......	89.8	......
Calcium carbonate	64.	251.	241.
Iron carbonate	.4	.2	1.
Undetermined	16.	49.6	......
Total	318.	580.	451.

Hypothetical combinations

Sodium nitrate	.08	......	.35
Sodium chloride	1.54	1.54	1.17
Sodium sulphate	9.09	5.56	7.23
Sodium carbonate	1.98	......	......
Magnesium sulphate	......	3.94	1.69
Magnesium carbonate	1.18	......	1.75
Calcium sulphate	......	5.24	......
Calcium carbonate	3.73	14.64	14 06
Iron carbonate	.02	.01	.06
Undetermined	.93	2.89	......
Total	18.55	33.82	26.31

waters in northeastern Illinois—Continued

Lake Ravinia Park	Lake Waukegan (C. & N. W. Station)	Lake Waukegan (E. of Station)	Lake Waukegan (E. of Station)	Lake Zion City (Shiloh Park)
Ravinia Park Association	C. & N. W. R. R.	North Shore Con. Gas Co. Old Well	North Shore Con. Gas Co. New Well	City
1096	2200	82	145	1568
161	......	......	115	167±
75	Flows 10	Flows 6	Flows 10	Floys 200±
Aug. 25, 1914	Sept. 9, 1914	Sept. 9, 1914	Sept. 9, 1914	Sept. 10, 1914

(parts per million)

120.	84.	100.	92.	104.
.6	.4	.8	.4	.4
.0	.20	.16	.20	.52
.0	.88	.7	.88	2.29
41.	16.	27.	40.	20.
276.2	173.2	136.2	145.6	260.
739.	555.	496.	547.	698.
263.	252.	223.	246.	247.
136.	104.	......	22.	204.

(parts per million)

......	1.2	1.	1.2	3.1
67.7	26.4	44.6	66.	33.
220.2	108.	133.5	184.4	95.4
......	......	......	......	......
144.	100.8	57.6	26.4	72.
......	......	43.7	58.8	......
21.8	27.2	......	......	195.8
263.	252.	171.	176.	247.
1.2	.8	1.7	.4	.8
21.1	38.6	42.9	33.8	50.9
739.	555.	496.	547.	698.

(parts per U. S. gallon)

......	.07	.06	.07	.18
3.95	1.54	2.60	3.85	1.92
12.84	6.30	7.79	10.75	5.56
......	......	......	......	......
8.40	5.88	3.36	1.54	4.20
......	......	2.55	3.43	......
1.27	1.59	......	......	11.42
15.34	14.70	9.97	10.27	14.41
.07	.05	.10	.02	.05
1.23	2.25	2.50	1.97	2.97
43.10	32.38	28.93	31.90	40.71

TABLE II.—*Boiler analyses of underground*

County	Lake	La Salle	La Salle
Town	Zion City (Edinah Park)	Grand Ridge (Waterworks)	Marseilles (Waterworks)
Owner	City	Village	Consumer's Water & Light Co. Two Wells
Depth of well.....feet	1270+	160	800 & 600
Depth of casing.....feet	112±	146+ 14′ screen	100± (Combined)
Rate of pumping.....gals. per min.	Flows 125±	110	100±
Date sample was collected	Sept. 10, 1914	Sept. 17, 1915	Sept. 17, 1915

Determinations made

Magnesium (as $CaCO_3$)	56.	52.	136.
Iron	.6	.7	.2
Nitrate nitrogen	.0	......	......
Nitrate	.0	.33	2.12
Chlorine	10.	7.	92.
Sulphate	197.5	0.	100.
Residue	576.	331.	568.
Alkalinity (as $CaCO_3$)	252.	300.	290.
Non-carbonate hardness (as $CaCO_3$)	134.	—200.	24.

Hypothetical combinations

Sodium nitrate	......	......	3.
Sodium chloride	16.5	12.	152.
Sodium sulphate	102.1	......	114.
Sodium carbonate	......	212.	......
Magnesium sulphate	67.2	......	29.
Magnesium carbonate	......	44.	94.
Calcium sulphate	106.1	......	......
Calcium carbonate	252.	48.	178.
Iron carbonate	1.2	2.	......
Undetermined	30.9	13.	......
Total	576.	331.	570.

Hypothetical combinations

Sodium nitrate	......	......	.17
Sodium chloride	.96	.70	8.87
Sodium sulphate	5.96	......	6.65
Sodium carbonate	......	12.37	......
Magnesium sulphate	3.92	......	1.69
Magnesium carbonate	......	2.57	5.48
Calcium sulphate	6.19	......	......
Calcium carbonate	14.70	2.80	10.38
Iron carbonate	.07	.12	......
Undetermined	1.80	.76	......
Total	33.60	19.32	33.24

waters of northeastern Illinois—Continued

La Salle Marseilles	La Salle Marseilles	La Salle Marseilles	La Salle Marseilles	La Salle Mendota (N. of R. R. Station)
Crescent Paper Co.	E. T. Hanshue	Howe & Davidson Paper Mills	Howe & Davidson Paper Mills	I. C. R. R.
128	137	590	75	563
80±	35	To bed rock	......	135±
Flows 4	Flows ½	Flows 10	Flows 2	125±
Sept. 17, 1915	Sept. 17, 1915	Sept. 18, 1915	Sept. 18, 1915	July 26, 1915

(parts per million)

176.	176.	156.	180.	80.
0.	0.	.6	.3	2.
......	......	......	......	......
1.24	.71	1.06	1.06	5.30
190.	200.	130.	200.	14.
206.	212.	136.	206.	0.
895.	912.	698.	916.	348.
300.	280.	305.	300.	294.
68.	112.	40.	76.	—74.

(parts per million)

2.	1.	1.	1.	7.
313.	330.	215.	330.	23.
209.	155.	145.	197.	......
......	......	......	......	76.
82.	134.	48.	91.	......
91.	54.	97.	87.	67.
......	......	......	......	......
192.	244.	189.	196.	140.
......	......	1.	1.	4.
6.	......	2.	13.	......
895.	918.	698.	916.	317.

(parts per U. S. gallon)

.12	.06	.06	.06	.41
18.26	19.25	12.54	19.25	1.34
12.19	9.04	8.46	11.49	......
......	......	......	......	4.43
4.78	7.82	2.80	5.31	......
5.31	3.15	5.66	5.07	3.91
......	......	......	......	......
11.20	14.23	11.02	11.43	8.17
......	......	.06	.06	.23
.35	......	.12	.76	......
52.21	53.55	40.72	53.43	18.49

TABLE II.—*Boiler analyses of underground*

County	La Salle	La Salle	La Salle
Town	Mendota (E. of R. R. Station)	Ottawa (Waterworks)	Ottawa (Waterworks)
Owner	C. B. & Q. R. R.	City Well No. 1	City Well No. 2
Depth of well .... feet	480	1449	1200
Depth of casing .... feet	136	285±	285±
Rate of pumping .... gals. per min.	200±	200	200
Date sample was collected	July 26, 1915	July 28, 1915	July 28, 1915

Determinations made

Magnesium (as $CaCO_3$)	80.	108.	92.
Iron	2.5	.2	.4
Nitrate nitrogen	......	......	......
Nitrate	2.12	1.41	2.12
Chlorine	13.	23.	38.
Sulphate	0.	0.	13.
Residue	382.	359.	402.
Alkalinity (as $CaCO_3$)	333.	326.	320.
Non-carbonate hardness (as $CaCO_3$)	—104.	—72.	—84.

Hypothetical combinations

Sodium nitrate	3.	2.	3.
Sodium chloride	21.	38.	63.
Sodium sulphate	......	......	19.
Sodium carbonate	110.	76.	89.
Magnesium sulphate	......	......	......
Magnesium carbonate	67.	91.	77.
Calcium sulphate	......	......	......
Calcium carbonate	149.	146.	144.
Iron carbonate	5.	......	......
Undetermined	......	......	......
Total	355.	353.	395.

Hypothetical combinations

Sodium nitrate	.17	.12	.17
Sodium chloride	1.69	2.21	3.67
Sodium sulphate	......	......	1.11
Sodium carbonate	6.41	4.43	5.19
Magnesium sulphate	......	......	......
Magnesium carbonate	3.91	5.31	4.49
Calcium sulphate	......	......	......
Calcium carbonate	8.69	8.52	8.40
Iron carbonate	.29	......	......
Undetermined	......	......	......
Total	21.16	20.59	23.03

waters of northeastern Illinois—Continued

La Salle Ottawa (La Salle St.)	La Salle Ottawa	La Salle Ottawa	La Salle Ottawa (Michigan & Champlain Sts.)	La Salle Peru (Waterworks)
J. P. Catlin	Chicago Fire Brick & Retort Co.	Chicago Fire Brick & Retort Co.	Ottawa Brewery	City
1800±	400±	600±	310	1505?
......	188±	200±	80±	
Flows 3	Flows 8	10	75	100±
July 29, 1915	July 29, 1915	July 29, 1915	July 28, 1915	July 26, 1915

(parts per million)

176.	120.	128.	108.	92.
6.	2.	.2	.1	1.7
......	......	......	......	......
1.06	1.76	1.06	1.41	1.77
2000.	43.	36.	23.	245.
62.	40.	47.	0.	65.
3707.	468.	475.	373.	845.
255.	328.	325.	326.	314.
376.	0.	—32.	76.	—100.

(parts per million)

1.	2.	1.	2.	2.
2954.	71.	59.	38.	404.
......	......	70.	......	96.
$MgCl_2$ 165.	59.	34.	76.	106.
......	......	......	......	......
$CaCl_2$ 148.	101.	108.	91.	77.
88.	......	......	......	......
255.	208.	165.	146.	122.
12.	4.	......	......	4.
......	......	......	......	......
3623.	445.	437.	353.	811.

(parts per U. S. gallon)

.06	.11	.58	.12	.12
172.30	4.14	3.44	2.22	23.57
......	3.44	4.08	......	5.60
($MgCl_2$) 9.62	.....	1.98	4.43	6.18
......	......	......	......	......
($CaCl_2$) 8.63	5.89	6.30	5.30	4.49
5.13	......	......	......	......
14.87	12.13	9.62	8.52	7.12
.70	.23	......	......	.23
......	......	......	......	......
211.31	25.94	26.00	20.59	47.31

TABLE II.—*Boiler analyses of underground*

County	La Salle	La Salle	La Salle
Town	Peru	Streator (E. Plant)	Streator
Owner	Illinois Zinc Co.	American Bottle Co.	Western Glass Co.
Depth of well ... feet	......	700±	587
Depth of casing ... feet	......	200±	200±
Rate of pumping ... gals. per min.	......	97	60±
Date sample was collected	Jan. 9, 1916	Aug. 10, 1915	Aug. 10, 1915

Determinations made

Magnesium (as $CaCO_3$)	112.	112.	116.
Iron	3.	.1	.2
Nitrate nitrogen	0.	......	......
Nitrate	0.	1.8	1.4
Chlorine	205.	325.	325.
Sulphate	76.	45.	36.
Residue	743.	958.	963.
Alkalinity (as $CaCO_3$)	302.	355.	370.
Non-carbonate hardness (as $CaCO_3$)	—144.	—128.	—136.

Hypothetical combinations

Sodium nitrate	......	2.	2.
Sodium chloride	338.	536.	536.
Sodium sulphate	11.2	67.	53.
Sodium carbonate	47.	135.	144.
Magnesium sulphate	......	......	......
Magnesium carbonate	94.	94.	97.
Calcium sulphate	......	......	......
Calcium carbonate	146.	115.	118.
Iron carbonate	6.	.2	.4
Undetermined	......	8.8	12.6
Total	743.	958.	963.

Hypothetical combinations

Sodium nitrate	......	.12	.12
Sodium chloride	19.72	31.26	31.26
Sodium sulphate	6.53	3.91	3.09
Sodium carbonate	2.74	7.87	8.40
Magnesium sulphate	......	......	......
Magnesium carbonate	5.48	5.48	5.66
Calcium sulphate	......	......	......
Calcium carbonate	8.52	6.71	6.88
Iron carbonate	.35	.01	.02
Undetermined	......	.51	.73
Total	43.34	55.87	56.16

waters in northeastern Illinois—Continued

McHenry	McHenry	McHenry	Will	Will
North Crystal Lake	Woodstock	Woodstock	Joliet	Joliet
(Waterworks)	(Waterworks)	(Near C. & N. W. R. R. Sta.)	(110 W. Jefferson St.)	(210 Collins St.)
City	City	Oliver Typewriter Co.	Adler Packing Co.	Joliet Citizen's Brewery
285	1000±	1211	344	1350
260	To bed rock	980	60±	150
200±	160	120	35±	50±
Sept. 28, 1914	Sept. 28, 1914	Sept. 26, 1914	Sept. 27, 1915	Sept. 24, 1915

(parts per million)

112.	156.	162.	236.	236.
.8	1.2	2.2	.2	0.
.3	.2	.0	......	......
1.3	.9	.0	6.2	26.5
17.	2.	4.	50.	53.
7.	.0	26.3	215.	285.
328.	390.	441.	761.	842.
294.	380.	380.	330.	300.
—44.	—20.	—40.	200.	244.

(parts per million)

1.8	1.2	......	9.	36.
28.	3.3	6.6	83.	87.
10.3	......	38.8	34.	74.
46.6	21.2	42.4	......	......
......	......	......	240.	283.
94.1	131.	134.4	30.	......
......	......	......	......	11.
138.	204.	180.	294.	300.
1.6	2.5	4.6	......	......
7.6	26.8	34.2	71.	51.
328.	390.	441.	761.	842.

(parts per U. S. gallon)

.10	.07	......	.52	2.10
1.63	.19	.38	4.84	5.07
.60	......	2.26	1.98	4.32
2.72	1.24	2.46	......	......
......	......	......	14.00	16.51
5.49	7.64	7.83	1.75	......
......	......	......	......	.64
8.05	11.90	10.50	17.15	17.50
.09	.15	.27	......	......
.44	1.56	2.00	4.14	2.97
19.12	22.75	25.70	44.38	49.11

TABLE II.—*Boiler analyses of underground*

County	Will	Will	Will
Town	Joliet (Michigan & Benton Sts.	Joliet (142 S. Bluff St.)	Joliet (812 N. Scott St.)
Owner	Moore Stove Co.	E. Porter Brewery	F. Sehring Brewery
Depth of well ... feet	503	512	1575
Depth of casing ... feet	175	......	......
Rate of pumping ... gals. per min.	35±	20	50
Date sample was collected	Sept. 23, 1915	Sept. 24, 1915	Sept. 23, 1915

Determinations made

Magnesium (as $CaCO_3$)	348.	280.	352.
Iron	.2	.2	0.
Nitrate nitrogen	......	......	......
Nitrate	28.3	8.8	19.4
Chlorine	72.	320.	107.
Sulphate	516.	198.	561.
Residue	1315.	1289.	1379.
Alkalinity (as $CaCO_3$)	370.	310.	355.
Non-carbonate hardness (as $CaCO_3$)	452.	408.	504.

Hypothetical combinations

Sodium nitrate	39.	12.	27.
Sodium chloride	119.	297.	177.
Sodium sulphate	121.	$MgCl_2$ 188.	114.
Sodium carbonate	......	......	......
Magnesium sulphate	418.	94.	422.
Magnesium carbonate	......	......	......
Calcium sulphate	141.	174.	208.
Calcium carbonate	370.	310.	355.
Iron carbonate	......	......	......
Undetermined	107.	214.	76.
Total	1315.	1289.	1379.

Hypothetical combinations

Sodium nitrate	2.27	.70	1.57
Sodium chloride	6.94	17.32	10.32
Sodium sulphate	7.06	$MgCl_2$ 10.97	6.65
Sodium carbonate	......	......	......
Magnesium sulphate	24.38	5.48	24.62
Magnesium carbonate	......	......	......
Calcium sulphate	8.22	10.15	12.13
Calcium carbonate	21.58	18.08	20.71
Iron carbonate	......	......	......
Undetermined	6.24	12.48	4.43
Total	76.69	75.18	80.43

waters of northeastern Illinois—Concluded

Will Rockdale (Waterworks)	Will Rockdale	Winnebago Rockford	Winnebago Rockford	......
Village	American Can Co.	Nelson Hotel	Trust Building	......
				......
662	640	400±	400	......
260	135	To bed rock	To bed rock	......
160	40	15	10	......
Sept. 24, 1915	Sept. 24, 1915	Sept. 29, 1914	Sept. 29, 1914	......

(parts per million)

88.	208.	196.	156.	......
.4	.1	.0	.0	......
......	......	.5	3.2	......
.53	7.4	2.2	14.1	......
47.	22.	26.	34.	......
116.	206.	71.6	47.7	......
530.	695.	528.	468.	......
290.	370.	318.	330.	......
—84.	76.	96.	62.	......

(parts per million)

1.	10.	3.	19.3	......
78.	36.	18.5	41.7	......
172.	1.97	......	......	......
89.	......	($MgCl_2$) 19.9	($MgCl_2$) 11.7	......
......	91.	89.7	59.7	......
74.	111.	84.	78.9	......
......	......	......	......	......
118.	238.	218.	236.	......
1.	......	.0	.0	......
......	12.	94.9	20.7	......
533.	695.	528.	468.	......

(parts per U. S. gallon)

.06	.58	.17	1.12	......
4.55	2.10	1.08	2.43	......
10.03	11.49	......	......	......
5.19	......	($MgCl_2$) 1.16	($MgCl_2$) .68	......
......	5.31	5.23	3.47	......
4.32	6.47	4.90	4.59	......
......	......	......	......	......
6.88	13.88	12.71	13.76	......
.06	......	.00	.00	......
......	.70	5.53	1.20	......
31.09	40.53	30.78	27.25	......

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